DOCUMENT RESUME

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TITLE Sheet Metal Specialist 13-1. Military Curriculum Materials for Vocational and Technical Education.

INSTITUTION Chanute AFB Technical Training Center, Ill.

PUB DATE 75

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EDRS PRICE MF02/PC23 Plus Postage.

DESCRIPTORS Assembly (Manufacturing); Behavioral Objectives; Competence; *Construction (Process); *Construction Materials; Correspondence Study; Hand Tools; Heating; Independent Study; *Job Skills; Job Training; Learning Activities; Mathematical Applications; Metal Working; *Occupational Information; Postsecondary Education; Roofing; Secondary Education; *Sheet Metal Work; Structural Elements (Construction); Supervision; Supervisory Methods; Technical Education; Test Items; Vocational Education; Welding; Workbooks

IDENTIFIERS Military Curriculum Project

ABSTRACT

This course, adapted from military curriculum materials for use in vocational and technical education, provides training in the theory and practice of sheet metal work. Designed for student self-instruction (such as a correspondence course), the text consists of four volumes. Volume 1 discusses shop mathematics, measurement and layout tools, working drawings, sheet metal layout, and sheet metals. Volume 2 covers fastening hardware and devices for sheet metal; sheet metal drilling and punching equipment; folding, forming, and seaming equipment; and soldering, spot welding, and sealants. In volume 3, instructions are given for assembling sheet metal components and making joint connections to fasten the components together. It also covers fabricating, installing, and repairing sheet metal components of heating and ventilating systems, fixed utility equipment, roofing, gutters, and downspouts. The final volume discusses supervisory responsibilities and personnel management, supervision of sheet metal fabrication and repair operations, determining job requirements, and inspections and evaluations. Each volume is accompanied by a student workbook containing a study reference guide, chapter objectives, chapter review exercises keyed to the text with answers, and volume review exercises keyed to the text. (KC)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

SHEET METAL SPECIALIST

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SHEET METAL SPECIALIST

Correspondence Course

13-1

Developed by:

United States Air Force

Development and Review Dates:

Unknown

Occupational Area:

Machine Shop

Cost:

Print Pages:

551

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Student self-study texts with companion workbooks containing chapter review exercises, answers, and volume review exercises

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Volume 1	–	*Career Field Fundamentals*	79	Flexible
		Workbook	47	
Volume 2	–	*Sheet Metalworking, Hardware, Tools, and Equipment*	54	Flexible
		Workbook	31	
Volume 3	–	*Fabrication, Installing, and Repairing Sheet Metal Components*	153	Flexible
		Workbook	64	
Volume 4	–	*Supervision and Management*	58	Flexible
		Workbook	38	

Supplementary Materials Required:

None

THE CENTER FOR VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

Expires July 1, 1978

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Course Description:

This course provides training in theory and the practical phase of sheet metal working. The duties of this position are:

- Use measurement and layout tools and read work drawings
- Layout sheet metal patterns
- Operate sheet metal cutting, drilling, punching, folding and seaming equipment
- Solder, spotweld and seal components
- Make seams to assemble metal components and joint connections to fasten the components
- Fabricate, install, and repair sheet metal components of heating and ventilating systems, fixed utility equipment, roofing, gutters, and downspouts
- Manage personnel, supervise sheet metal fabrication and repair operations, determine job requirements, inspect and evaluate work

The course materials are designed for student self-instruction. The four volumes of text materials include:

Volume 1	–	*Career Field Fundamentals* discusses shop mathematics, measurement and layout tools, working drawings, sheet metal layout, and sheet metals.
Volume 2	–	*Sheet Metalworking, Hardware, Tools, and Equipment* deals with fastening hardware and devices for sheet metal; sheet metal cutting equipment; drilling and punching equipment; folding, forming, and seaming equipment. Soldering, spot welding, and sealants are also discussed.
Volume 3	–	*Fabrication, Installing, and Repairing Sheet Metal Components* covers making seams to assemble sheet metal components and making joint connections to fasten the components together. It also covers fabricating, installing, and repairing sheet metal components of heating and ventilating systems, fixed utility equipment, roofing, gutters, and downspouts.
Volume 4	–	*Supervision and Management* discusses supervisory responsibilities and personnel management, supervision of sheet metal fabrication and repair operations, determining job requirements, and inspections and evaluations.

All except the first chapter of Volume I and Chapters 4 and 6 of Volume IV are appropriate for vocational programs. Chapter 1, Volume I deals with military career ladders. Volume IV, Chapter 4—Planning and Scheduling Work, and Chapter 6—On-The-Job Training, involve military specific applications to these subjects. These chapters were deleted in adapting the course for civilian use. Each volume is accompanied by a student workbook containing a study reference guide, chapter objectives, Chapter Review Exercises keyed to the text with answers, and Volume Review Exercises keyed to the text.

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53350 00 S01 7507

CHANGE SUPPLEMENT

CDC 53350

SHEET METAL SPECIALIST

(AFSC 53152)

IMPORTANT: Make the corrections indicated in this change supplement, Volumes 1, 2, 3, and 4, and insert new illustrations before beginning study of this CDC. This supplement is printed on one side only to permit cut-and-paste postings of lengthy changes, in case you care to post these changes in this manner.

CHANGES FOR THE TEXT: VOLUME 1

Cover sheet, line 4. Change "(AFSC 53350)" to "(AFSC 53152)."

Page ii, line 2. Change "Gunter Air Force Base" to "Gunter Air Force Station."

Page iii, para 3. Change "(TTOC)" to "/TTOXC."

Page iii, para 4, line 5. Change "Gunter AFB, Alabama" to "Gunter AFS AL."

Page iii, para 6, line 2. Change "October 1971" to "May 1975."

Page 1, para 3, line 4. Change "53330/50" to "53132/52."

Page 2. Delete chart 1; replace with new chart 1.

Page 3, col 2. Change "AFSC 53350" (at the top of the specialty description) to "AFSC 53152," and change "AFSC 53330" to "AFSC 53132."

Page 4, col 1, line 3. Delete "(1)."

Page 4, col 2. Delete lines 2 and 3.

Page 4, col 2, lines 4 and 5. Change "Completion of high school is desirable" to "Completion of high school with courses in shop mathematics, metalworking, or mechanical drawing is desirable."

Page 4, col 2, line 12. Change "25 is desirable" to "40 is mandatory."

Page 4, para 4 (Specialty Data). In line *a*, change "53350" to "53152"; in line *b*, change "53330" to "53132."

Page 4, figure 1 legend. Change "53330/50" to "53132/52."

Page 4, para 2-3, line 2. Change "53350). Figures 1 and 1A show" to "53152). Figure 1 shows."

Page 4, para 2-3, line 3. Change "53350" to "53152."

Page 4, para 2-4, line 13. Change "53330/50/70" to "53132/52/72."

Page 4, para 2-5, line 2. Change "53370" to "53172."

Page 4, para 2-6, line 2. Change "53690" to "53195."

Page 5, para 3-4, line 1. Change "*Manual*" to "*Regulation*" and "AFM" to "AFR."

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Page 5, para 3-4, line 2. Change *"Industrial Safety"* to *"Ground."*

Page 5, para 3-4, line 3. Change "is an important manual in" to "is important to."

Page 5, para 3-4, line 7. Change "AFM" to "AFR."

Page 5, para 3-8, line 1. Change *"Manual"* to *"Regulation"* and "AFM" to "AFR."

Page 5, para 3-8, line 7. Change "AFM" to "AFR."

Page 5, para 3-8, line 9. Change "Engineer Work Schedule" to "Engineer Weekly Work Schedule" and change "1829" to "1879."

Page 5, para 3-8, line 10. Change "Base Civil Engineer Job Order" to "Service Call/Job Order Record."

Page 11. Delete para 5-4 and para 5-5.

Page 11, para 5-7, lines 2 and 3. Cnange "each full workday including the time spent on the job" to "each hour of the workday." Delete the remainder of the paragraph.

Page 11, para 5-8. In line 1, change *"660"* to *"1734."* Delete the remainder of the paragraph and replace it with "AF Form 1734, BCE Daily Work Schedule, is the man-hour accounting form maintained by the controller."

Pages 11-12. Delete para 5-9.

Page 27, para 11-2, lines 17 and 18. Change the comma to a period after "decimals" and delete "called equivalents of an inch."

Page 37, para 12-6, line 10. Change "1, 211" to "1 to 11."

Page 38, para 12-9, line 7. Change "4-inch" to "3-inch."

Page 46, figure 60 legend. Change "protection" to "projection."

Page 73, para 18-47, line 5. Change "10" to "100."

Page 74, para 18-53, line 7. Change "b-" to "be-."

Page 87, para 21-2, line 3. Change "allows" to "alloys."

Page 91, para 23-7, line 4. Change "materal" to "material."

CHANGES FOR THE WORKBOOK: VOLUME I

Page 3, question 6, line 1. Change "53350/50" to "53132/52." Question 7, line 1. Change "53350" to "53132."

Page 4, question 13, line b. Change "AFM" to "AFR." Change line 1 to read *"Ground Accident Prevention Handbook."*

Page 5. Delete question 26.

Page 6. Delete questions 28 and 29.

Page 20. Delete questions 16 and 19.

Page 21. Delete question 27.

Page 26, answer 4. Change "53230 and 53330" to "53131 and 53132."

Page 26, answer 5. Change "533X0" to "531X2."

Page 26, answer 8. Change "AFM" to "AFR." Add *"Ground"* just before *"Accident."*

Page 27, answer 26. Change "26" to "30."

Page 27. Delete answer 27.

Page 27, answer 28. Change "28" to "27."

Page 27. Delete answers 29 and 30.

Page 35. Delete answers 16 and 19.

Page 36. Delete answer 27.

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MODIFICATIONS

Page 3 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHANGES FOR THE TEXT: VOLUME 2

Cover sheet, line 4. Change "(AFSC 53350)" to "(AFSC 53152)."

Page ii, line 2. Change "Gunter Air Force Base, Alabama" to "Gunter Air Force Station, Alabama."

Page iii, para 4, line 4. Change "(TTOC)" to ". TTOXC."

Page iii, para 4, lines 10-11. Change "Gunter AFB, Alabama 36114" to "Gunter AFS AL 36118."

Page iii, para 6, line 2. Change "1970" to "1975."

Page 11, para 4-1, col 2, line 15. Change "AFM" to "AFR."

CHANGES FOR THE WORKBOOK: VOLUME 2

Page 4, question 3, lines 1 and 2. Change "If the AF Form 1317, Maintenance Record Equipment," to "If the maintenance record folder."

Page 6. Delete question 25.

Page 10, question 25, line 2. Change "hold" to "hole."

Page 21, answer 2, lines 1 and 2. Change "AF Form 1317, Maintenance Record Equipment" to "The maintenance record folder."

Page 21. Delete answer 25.

Page 21, answer 32, line 1. Change "minimum" to "maximum."

CHANGES FOR THE TEXT: VOLUME 3

Cover sheet, line 3. Change title to "Sheet Metal Specialist."

Cover sheet, line 4. Change "(AFSC's 53330 and 53350)" to "(AFSC 53152)."

Page ii, line 2. Change "Base" to "Station."

Page iii, para 1, line 4. Change "Job" to "Specialty."

Page iii, para 1, lines 5 through 8. Delete the last sentence of the paragraph.

Page iii. Delete paragraphs 3 and 4.

Page iii, para 7, lines 2 and 3. Change address to "Tech Tng Cen/TTOXC, Chanute AFB IL 61868."

Page iii, para 8, line 5. Change "Gunter AFB, Alabama 36114" to "Gunter AFS AL 36118."

Page iii, para 9. Delete this line.

Page iii. Add para 11: "Material in this volume is technically accurate, adequate, and current as of May 1975."

Page 10, para 2-23, lines 15 through 17. Delete "(This sequence of bending operations is illustrated in figure 36 at the end of this chapter.)."

Page 13, para 3-4, lines 5 and 6. Delete "Notice that piece 2 can be forced 180° before joining with piece 1."

Page 17, para 3-16, col 2, line 4. Change "additions" to "allowances."

Page 35, para 6-6, line 8. Change "3" to "6."

Page 35, para 6-6, line 11. Change "12" to "9."

Page 42, figure 57. Move joint 2 and locate it between joints 3 and 4; at Room 11, next to 8" section, change "6" to "5."

Page 43, figure 58. In Item Identification column, change "Joint 1" to "Joints 1 and 3" and change "Joints 3, 4, and 5" to "Joints 4 and 5." In Quantity column, line 1 (regarding joints 1 and 3), change "1" to "2"; in line 2 (regarding joints 4 and 5), change "3" to "2"; in line 13 (regarding first listing of Standing S-Slips), change "4" to "6;" and in line 14 (regarding second listing of Standing S-Slips), change "12" to "10."

Page 44, para 6-44, line 1. Change "1 will be 36" x 57¼"; which" to "1 (and for joint 3) will be 36" x 57¼"; both of these joints."

Page 44, para 6-44, line 3. Change "joint 1" to "joints 1 and 3."

Page 44, para 6-44, line 5. Change "pattern for joint 1" to "patterns for joints 1 and 3."

Page 44, para 6-45, line 2. Change "3, 4, and 5" to "4 and 5."

Page 45, figure 59, sheet 1, joint 3. Change 53¼" to 57¼".

Page 58, para 7-21, line 2. Change "nips" to "snips."

Page 59, para 7-30, lines 4 and 5. Delete "and bent over (with a mallet), as shown in views B and C of figure 16."

Page 116, para 3, line 2. Change "Job" to "Specialty."

Page 138, para 22-12, line 4. Change "A" to "C."

Page 138, para 22-12, line 8. Change "C" to "A."

Page 138, Figure 137. In view A, change "OVAL" to "ROUND;" in view C, change "ROUND" to "OVAL."

Foldout 1, trunk line B. Relocate the first transition (to the right of the turn vanes) to the area just after the words "TRUNK LINE B."

CHANGE FOR THE WORKBOOK: VOLUME3

Page 46, answer 5. Change "Four" to "Two."

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CHANGES FOR THE TEXT: VOLUME 4

Cover sheet, line 4. Change "(AFSC 53350)" to "(AFSC 53152)."

Page ii, line 4. Change "Gunter Air Force Base, Alabama 36114" to "Gunter Air Force Station, Alabama."

Page iii, para 3, line 1. Change "53350" to "53152."

Page iii, para 4, line 3. Change "(TTOC)Chanute AFB, ILL" to "(TTOXC, Chanute AFB IL."

Page iii, para 5, line 5. Change "Gunter AFB, Alabama" to "Gunter AFS AL."

Page iii, para 7, lines 1 and 2. Change "October 1971" to "May 1975."

Page 1, para 6, line 1. Change "63350" to "53152."

Page 2, para 1-3, line 6. Change "Job" to "Specialty."

Page 2, para 1-3, line 7. Change "53330/50/70" to "53132/52/72."

Page 2, para 1-3, lines 10, 11, and 12. Delete the sentence beginning "The title. . . ."

Page 2, para 1-3, line 13. Change "63350" to "53152."

Page 2, para 1-4, line 1. Change "53350" to "53152."

Page 3, para 1-9, line 3. Change "53330/50/70" to "53132/52/72."

Page 3, para 1-14, line 1. Change "Technicion" to "Technician" and change "53370" to "53172."

Page 3, para 1-14, line 8. Change "53370" to "53172."

Page 4, para 1-20, line 2. Change "53690" to "53195."

Page 4, para 1-20, line 11. Change "53690" to "53195."

Page 13, para 3-23, line 1. Change "assigns" to "assigns."

Page 13, para 3-23, line 14. Change "CEC 53350" to "this CDC."

Page 17, para 3-35, line 7. Change "53350" to "53152."

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MODIFICATIONS

Pages 7- 12 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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CDC 53350

SHEET METAL SPECIALIST

(AFSC 53350)

Volume 1

Career Field Fundamentals

13-1

Extension Course Institute

Air University

DEPARTMENT OF THE AIR FORCE
MCMXLVII
UNITED STATES OF AMERICA

PREPARED BY CHANUTE AIR FORCE BASE, ILLINOIS, AIR TRAINING COMMAND

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE BASE, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

WELCOME TO this career development course. We hope you enjoy your training in the very old and important occupation of metalworking. Do you know that working with metals is one of man's oldest skills? In fact, man's work with metals is so important that whole eras of history have been classified according to metals such as the bronze age and iron age. It is not unreasonable to imagine that our present era will be remembered as the sheet metal age. Just look around you and count the many articles made from sheet metal. Each item you see represents man's progress in the fabrication of sheet metal articles. Or think of the modern automobile, which is a marvel of sheet metal construction. What do you suppose an automobile would weigh or cost if it were made of wood or metal castings instead of sheet metal?

This volume contains career field fundamentals which will be used throughout your training period as well as in day-to-day work activities in the sheet metal shop. Take this training seriously and give it your best effort, because the results will benefit YOU as well as furnish the Air Force with quality repair, fabrication, and installation of sheet metal components. Completion of this career development course will help you pass the course examination (CE).

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB, IL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of ~~October 1971~~. May 1975.

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MODIFICATIONS

Chapter 1 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Shop Mathematics

THE SHOP mathematics discussed in this chapter includes reading graduated scales such as rules and tapes, use of fractional and decimal numbers, solving equations and formulas, and measurement of plane and solid geometric figures which are related to sheet metalwork. You will frequently use shop mathematics in such jobs as developing layouts and patterns for sheet metal repairs, fabrications, and installations.

2. If you have little background in arithmetic and geometry, this chapter will improve your ability to perform most of the mathematical problems related to sheet metalwork. If you have a good background in these functions of mathematics, this text and review exercises will serve to refresh your memory. If you understand this chapter, your work should be more accurate and you should acquire the knowledge to pass the course examination.

3. The portions of the chapter which discuss geometric figures are accompanied by formulas for determining dimensions, area, and volume. Review exercises in the Workbook serve as a review of the text as well as a check of your understanding. Some of the review exercises involve a single item of information, whereas others may require use of several areas to solve a problem. Since so much of your work involves measuring with rules and tapes, let us begin with a study of reading graduated scales.

6. Reading Graduated Scales

6-1. As a sheet metal specialist, you will use graduated scales such as measuring rules, tapes, squares, micrometers, protractors, twist drill size gages, adjustment gages on metal cutting machines, and thickness gages. These measuring devices used in most sheet metalwork are graduated in inches and feet. It is very important for you to understand fractions so that you can measure fractional distances. For example, you will frequently measure distances or thicknesses in fractional parts of the inch, such as eighths, sixteenths, thirty-seconds, and sixty-fourths.

6-2. In figure 3, you can see the fractional parts of an inch that are commonly used. As you study the rule shown in the upper part of this figure, notice that one side of the rule is graduated in eighths of an inch and the other side in sixteenths. The rule illustrated in the lower part of the figure is graduated in thirty-seconds and sixty-fourths. You must learn to correctly read figures like these, because correct measurement is essential for most jobs involving layout, fabrication, repair, and installation of sheet metal articles and components.

6-3. As a brief review of your ability to read graduated scales, use the upper rule in figure 3 and locate the marks representing $1\frac{5}{8}$ inches and $1\frac{7}{16}$ inches. In the lower rule locate the marks representing $\frac{17}{32}$ inch and $\frac{35}{64}$ inch.

6-4. To further improve your skill in reading graduated scales, refer to the 6-inch rule illustrated in figure 4 and verify each of the following.

Position 9 is 6 inches
Position 7 is 4 inches
Position e is $3\frac{1}{8}$ inches
Position c is $1\frac{13}{16}$ inches
Position 2 is $\frac{25}{32}$ inches

6-5. Although the importance of correctly reading fractional parts of inches has been emphasized, you must also use care in correctly reading measuring tapes that are graduated in feet and inches. For example, the measurement of a panel to be cut may be 2 feet wide and 7 feet 3½ inches long. (These measurements may be abbreviated as 2 ft. by 7 ft. 3½ in. or as 2′ x 7′ 3½″.) The measurements may be made with a steel tape (such as a power-return tape or push-pull rule), folding rule, or the measuring gage on squaring shears. Using any of these requires the measurement to be made from the exact edge of the metal to the right mark on the graduated scale.

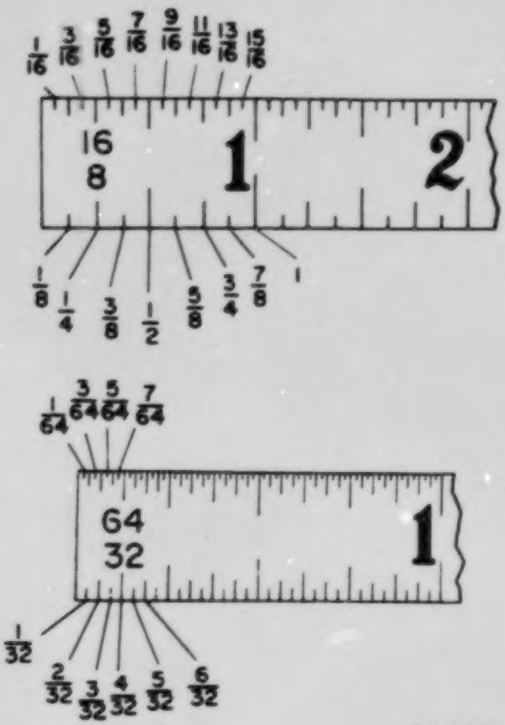

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Figure 3. Graduated scales.

7. Fractions

7-1. A fraction in which the numerator is *smaller* than the denominator is called a proper fraction such as $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{7}{8}$.

7-2. Improper fractions are those with a numerator *larger* than the denominator such as $\frac{9}{8}$. The fraction $\frac{9}{8}$ may be considered to be the sum of $\frac{8}{8}$ plus $\frac{1}{8}$. It is customary to change improper fractions to mixed numbers by dividing the numerator by the denominator. The quotient (or result) is expressed as a whole number followed by a fraction in which the remainder is the numerator, and the denominator is the same as before. For example: $\frac{9}{8} = 1\frac{1}{8}$, since 8 is contained in 9 one time with a remainder of 1.

7-3. Sometimes, as in multiplication, it is desirable to convert a mixed number to an improper fraction. This can be done by reversing the above process. To accomplish this conversion, multiply the whole number by the denominator of the accompanying fraction and add the numerator; then use this number as the new numerator, and the denominator remains the same as in the mixed number. Thus, to change $2\frac{3}{4}$ to an improper fraction, multiply 2×4 and get 8; and $8 + 3 = 11$. Putting this 11 over the original denominator 4 you now have $\frac{11}{4}$.

7-4. When both the numerator and denominator of a fraction contain a common factor, the fraction should be reduced by this factor. That is, the numerator and the denominator are divided by the common factor. For example, the fraction $\frac{6}{8}$ can be reduced by dividing both the 6 and the 8 by 2. The answer is $\frac{3}{4}$, which has the same value as the original $\frac{6}{8}$. This process is called reducing a fraction to its lowest terms. If both the numerator and denominator of a fraction are either multiplied or divided by the same number, the value of the fraction is not changed.

7-5. **Multiplying Fractions.** Perhaps the simplest operation with fractions is multiplication such as $\frac{1}{4} \times \frac{3}{4} = \frac{3}{16}$ and $2 \times \frac{3}{4} = \frac{6}{4} = 1\frac{2}{4} = 1\frac{1}{2}$. When mixed numbers are to be multiplied, first change each to an improper fraction and proceed.

a. $1\frac{2}{3} \times 3\frac{1}{2} = \frac{5}{3} \times \frac{7}{2} = \frac{35}{6} = 5\frac{5}{6}$
b. $1\frac{1}{4} \times 2\frac{1}{2} = \frac{5}{4} \times \frac{5}{2} = \frac{25}{8} = 3\frac{1}{8}$

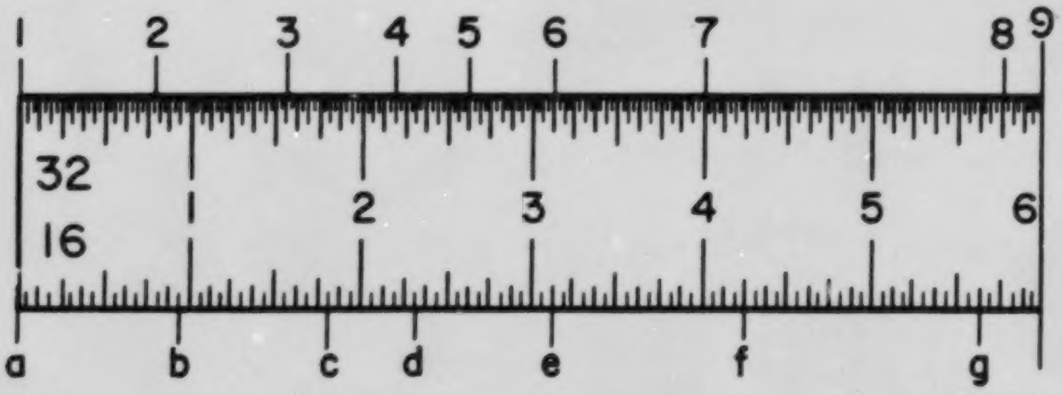

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Figure 4. Six-inch rule.

7-6. Frequently, you can simplify the multiplication of fractions by performing certain divisions of numerators and denominators before proceeding with the indicated multiplication. For instance, you can multiply $\frac{3}{10}$ by $\frac{4}{9}$ in the following way.

Example:

$$\frac{\overset{1}{\cancel{3}}}{\underset{5}{\cancel{10}}} \times \frac{\overset{2}{\cancel{4}}}{\underset{3}{\cancel{9}}} = \frac{2}{15}$$

7-7. Here you divided (commonly called canceling) before performing the indicated multiplication. The numerator 3 and the denominator 9 were divided by the common factor 3. The numerator 4 and the denominator 10 were divided by the common factor 2. Then, with the numerators 1 and 2 and the denominators 5 and 3, you easily arrived at the answer $\frac{2}{15}$.

7-8. **Adding Mixed Numbers.** In adding mixed numbers, first add the whole numbers just as in ordinary addition; then add the fractions after changing to common denominators. If the sum of the fractions is an improper fraction, change it to a mixed number or a whole number, add the whole numbers, and keep the remaining fraction as part of the answer.

Examples:

a.

$$\begin{array}{rcr} 12\frac{1}{6} & = & 12\frac{3}{18} \\ 14\frac{2}{3} & = & 14\frac{12}{18} \\ 5\frac{1}{9} & = & 5\frac{2}{18} \\ \hline & & 31\frac{17}{18} \end{array}$$

b.

$$\begin{array}{rcr} 120\frac{3}{4} & = & 120\frac{6}{8} \\ 52\frac{5}{8} & = & 52\frac{5}{8} \\ 23\frac{1}{2} & = & 23\frac{4}{8} \\ \hline & & 195\frac{15}{8} = \left(\frac{15}{8} = 1\frac{7}{8}\right) \end{array}$$

So

$$195 + 1\frac{7}{8} = 196\frac{7}{8}$$

7-9. **Subtracting Mixed Numbers.** When the fraction in the top number (minuend) is greater than the fraction in the lower number (subtrahend), subtract the whole part from the whole part and the fraction from the fraction.

Examples:

a.

$$\begin{array}{r} 22\frac{5}{8} \\ -12\frac{3}{8} \\ \hline 10\frac{1}{8} \end{array}$$

b.

$$\begin{array}{rcr} 22\frac{3}{4} & = & 22\frac{3}{4} \\ -12\frac{1}{2} & = & 12\frac{2}{4} \\ \hline & & 10\frac{1}{4} \end{array}$$

7-10. If the upper fraction is the smaller of the two, first borrow one whole unit from the top whole number and convert it into the fractional equivalent of a whole number. Add this and the fraction you already have; then proceed with the subtraction.

Examples:

$$\begin{array}{rcr} 29\frac{1}{4} & = & 28\frac{5}{4} \\ -15\frac{3}{4} & = & 15\frac{3}{4} \\ \hline & & 13\frac{2}{4} = 13\frac{1}{2} \end{array}$$

8. Decimals

8-1. In sheet metalwork, as in many other fields, it is often advantageous to use a form of fraction known as a *decimal.* Decimal fractions are tenth parts of a unit indicated by tenths, hundredths, thousandths, etc. The denominator of a decimal is the numeral 1, followed by one or more zeros. For this reason, it is possible to use an abbreviated method of writing decimal fractions. Instead of drawing a line below the numerator and writing the denominator below, the line and denominator are omitted in a decimal fraction and replaced by a decimal point.

8-2. **Reading Decimals.** The decimal point is written at the left of the number expressing the numerator. For example 0.5 is a decimal and is read point 5, or five tenths. Its value is the same as the fraction $\frac{5}{10}$.

8-3. Read a decimal precisely as if it were a whole number, and then give it the name of the lowest decimal place. Point 1 (0.1) is read one tenth, point 01 (0.01) is read one hundredth, point 001 (0.001) is read one thousandth, etc.

8-4. An example of decimals you will be using is a number 39 twist drill, which is 0.099 inch in diameter; the decimal 0.099 is read ninety-nine thousandths. Another example is 24-gage sheet metal, which is 0.025 inch thick; the decimal 0.025 is read twenty-five thousandths.

8-5. A mixed number with decimals such as 1.25 is read one and twenty-five hundredths, or simply one point twenty-five.

8-6. **Changing Fractions to Decimals.** To change a common fraction to a decimal fraction, divide the numerator by the denominator.

Example:

$$\frac{7}{8} \qquad \begin{array}{r} 0.\ 875 \\ 8\ \overline{)7.\ 000} \\ 6\ 4 \\ \hline 60 \\ 56 \\ \hline 40 \\ 40 \\ \hline \end{array}$$

Therefore,

$$\frac{7}{8} = 0.875$$

8-7. **Changing Decimals to Fractions.** To change a decimal fraction to a common fraction, omit the decimal point, write the understood denominator, and reduce to lowest terms.

Example:

$$0.875 = \frac{875}{1000} = \frac{35}{40} = \frac{7}{8}$$

8-8. **Using Decimal Equivalent Charts.** Figure 5 is a decimal equivalent chart which you can use to convert fractions to decimals and decimals to fractions without using the preceding mathematical procedures. The chart contains the decimal equivalents of all fractional values from $\frac{1}{64}$ to $\frac{64}{64}$. In shop work, you will save time by using the decimal equivalent charts; however, sometimes you will encounter fractions that are not on the chart and must be figured arithmetically.

Example: Use figure 5 and determine the decimal equivalent of $\frac{1}{64}$, $\frac{5}{32}$, $\frac{5}{16}$, and $\frac{7}{8}$.

$$\frac{1}{64} = 0.015625$$
$$\frac{5}{32} = 0.15625$$
$$\frac{5}{16} = 0.3125$$
$$\frac{7}{8} = 0.875$$

8-9. **Adding Decimals.** To add numbers containing decimals, the decimal points must be aligned in a vertical column.

Example: Find the sum of 13.01, 0.037, and 1.3.

$$\begin{array}{r} 13.01 \\ 0.037 \\ 1.3 \\ \hline 14.347 \end{array}$$

8-10. **Subtracting Decimals.** To subtract decimal fractions, align the decimal points as in addition and determine the difference.

Example: Subtract 2.84 from 15.1.

$$\begin{array}{r} 15.10 \\ -\ 2.84 \\ \hline 12.26 \end{array}$$

8-11. **Multiplying Decimals.** To multiply decimal numbers, place the multiplier under the multiplicand, disregarding the position of the decimal points. Multiply as with whole numbers, and in the product point off as many decimal places as there are decimal places in both multiplier and multiplicand, beginning at the right, and adding ciphers (zeros) is necessary.

Examples:

$$\begin{array}{ccc} a. & b. & c. \\ \begin{array}{r} .25 \\ 2.5 \\ \hline 125 \\ 50 \\ \hline .625 \end{array} & \begin{array}{r} 11.25 \\ .75 \\ \hline 5625 \\ 7875 \\ \hline 8.4375 \end{array} & \begin{array}{r} .05 \\ .5 \\ \hline .025 \\ \\ \\ \end{array} \end{array}$$

Decimal Equivalents									
FRACTION	16TH.	32ND.	64TH.	DECIMAL	FRACTION	16TH.	32ND.	64TH.	DECIMAL
			1	015625				33	515625
		1	2	03125			17	34	53125
			3	046875				35	546875
	1	2	4	0625		9	18	36	5625
			5	078125				37	578125
		3	6	09375			19	38	59375
			7	109375				39	609375
1/8	2	4	8	125	5/8	10	20	40	625
			9	140625				41	640625
		5	10	15625			21	42	65625
			11	171875				43	671875
	3	6	12	1875		11	22	44	6875
			13	203125				45	703125
		7	14	21875			23	46	71875
			15	234375				47	734375
1/4	4	8	16	250	3/4	12	24	48	750
			17	265625				49	765625
		9	18	28125			25	50	78125
			19	296875				51	796875
	5	10	20	3125		13	26	52	8125
			21	328125				53	828125
		11	22	34375			27	54	84375
			23	359375				55	859375
3/8	6	12	24	375	7/8	14	28	56	875
			25	390625				57	890625
		13	26	40625			29	58	90625
			27	421875				59	921875
	7	14	28	4375		15	30	60	9375
			29	453125				61	953125
		15	30	46875			31	62	96875
			31	484375				63	984375
1/2	8	16	32	500	1	16	32	64	1 000

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Figure 5. Decimal equivalent chart.

9. Equations and Formulas

9-1. In this section, you are entering into another branch of mathematics that is important to sheet metal specialists. Do not treat it lightly, because an understanding of this phase and the successful use of formulas will eliminate difficulties and wasted time. The use of formulas in the shop is not difficult, because it deals primarily with fundamentals of arithmetic and simple algebra.

9-2. **Equations.** An equation is a mathematical statement which expresses the equality of two or more quantities. For example, the statement $5 + 4 = 9$ is an equation. It expresses in an abbreviated form the fact that the sum of $5 + 4$ is equal to 9. Furthermore, if three quantities such as a, b, and c are given, the whole equals the sum of the parts, the equation $a + b + c = x$ can be formed which will identify x as the unknown side of the equation. *Example:* a represents a length of 1 inch; b, 2 inches; and c, 3 inches. Now, you can solve the equation by substituting the numerical values and adding $1 + 2 + 3$, which is 6. Thus, $a + b + c = 6$, because x is equal to the sum of the parts $(a + b + c)$.

9-3. An equation is always divided into two parts by the sign of equality (=). These two parts of the equation are called members of the equation or the two sides of the equation.

9-4. It is necessary that the equation be balanced *at all times*. If two unequal weights are placed in the pans of a common scale, the scale will not balance. In a like manner, if you say

$2 + 2 = 2 + 3$ the equation does not balance. It should read $2 + 2 = 1 + 3$, or other equal values. In an equation, changes may be made provided the equality is maintained. This means that you may add or subtract the same quantity from both sides of an equation or multiply or divide both sides of an equation by the same quantity without changing the value of the equation.

9-5. **Formulas.** A formula is a special type of equation which expresses a certain fact, law, or relation by means of symbols or letters. There are several reasons why a formula is used in solving many shop problems. First of all, a formula is more compact, making it easier for the eye to distinguish the whole meaning of the law or rule at a glance. Secondly, it is easier for an individual to memorize a few symbols rather than a paragraph of explanations. For example, the law for determining the area of a rectangle is usually stated as follows: The area of a rectangle is equal to the length of one side multiplied by the length of the other side. This law, however, can be stated in simpler form by the formula $A = bh$, where b represents the base and h represents the height or altitude. In this formula, you are given a full picture of how to attain the area of a rectangle. If you will notice, this formula eliminates using long terms that are difficult to interpret. In short, you have a simplified expression of the same law or rule.

9-6. **Abbreviations Used in Formulas.** Since formulas are equations which involve a sort of mathematical shorthand, you must understand the meaning of the various symbols used. From your experiences in school arithmetic, you should recall the meaning of the plus sign (+), minus sign (−), multiplication sign (×), division sign (÷), and the equal sign (=). You should also recall that the exponent (^{2}) means to square a number. For example, 2^2 means 2×2, and 2^3 means $2 \times 2 \times 2$. Now in formulas such as $A = bh$, we mean that area equals the base times the height. In the formula $A = \frac{bh}{2}$, we mean that area (A) is equal to the base (b) times the height (h) divided by 2. An abbreviation often used when figuring the dimensions of circles is the Greek letter (π), pronounced pi, which is used in mathematics to represent the numerical figure 3.1416. The number 3.1416 is the ratio of the distance around the circumference to the diameter of a circle. In the formula $a = \pi r^2$, we mean that the area of a circle is equal to 3.1416 times the radius squared.

9-7. **Transposition in Formulas.** The common method of working a formula is to place the known values on one side of the equal sign and the unknown values on the opposite side. For example, in the formula $A = bh$, the area of any rectangle (A) may be found if the base (b) is multiplied by the height (h). However, if the area and base are known we could solve for the height by transposing the formula to read $h = \frac{A}{b}$.

9-8. Here you have the same law but with a different arrangement for the purpose of finding the height when the area and base are known. To determine the values represented by different letters of the formula, it is necessary to know how a formula can be changed or transposed. Changing a formula in this way is known as transposition. The four general rules that apply to transposition are as follows:

9-9. *A single term preceded by a plus sign can be transferred to the other side of the equal sign if the plus sign is changed to a minus sign.* For example, the equation $x + 2 = 8$ can be changed to read $x = 8 - 2 = 6$.
Rule: You may subtract the same quantity from both sides of an equation without changing the value of the equation.

9-10. *A single term preceded by a minus sign can be transferred to the other side of the equal sign if the minus sign is changed to a plus sign.* For example, suppose in the equation $x - 2 = 6$, you want to find the value of x. To do this, transpose or change the -2 to the other side of the equation and change its − sign to +. Therefore, $x - 2 = 6$ can be changed to $x = 6 + 2 = 8$. Here all you have done is to add 2 to both sides of the equation which does not change the value of the equation.
Rule: You may add the same quantity to both sides of an equation without changing the value of the equation.

9-11. *Any member of an equation which multiplies all the other members on one side of the equal sign can be transposed to the other side of the equal sign if it is made to divide all the members on that side.* For example, again, consider the formula $A = bh$ and suppose we want to solve for h. According to this rule we can divide both sides by b, then cancel out the side with b in both numerator and denominator like this:

$$A = bh \text{ so } \frac{A}{b} = \frac{bh}{b}, \text{ or } \frac{A}{b} = h$$

Rule: Both sides of an equation may be divided by the same quantity without changing the value of the equation.

9-12. *Any member which divides all the other members on one side of the equal sign can be transposed or changed to the other side of the* *equal sign if it is made to multiply all the members on both sides of the equal sign.* As an example of this rule, consider the formula for finding the area of a triangle $A = \frac{bh}{2}$. If you need to transpose the formula in order to solve for h, proceed as follows. To transpose the denominator 2, multiply both side of the equation by the whole number 2 like this:

$$A = \frac{bh}{2}$$

so

$$A \times 2 = \frac{bh \times 2}{2}$$

or

$$2A = bh$$

Now to transpose the b to the other side of the equation, divide both sides by b and cancel b's like this:

$$\frac{2A}{b} = \frac{bh}{b} \quad \text{or} \quad \frac{2A}{b} = h$$

Rule: Both sides of an equation can be multiplied by the same quantity without changing the value of the equation.

10. Mensuration

10-1. The branch of mathematics that deals with lines, angles, surfaces, and solids is known as geometry. The particular branch of geometry that deals with the measurement of lines, angles, surfaces, and solids is known as mensuration. In laying out sheet metalwork, you will frequently make use of lines and angles in constructing various patterns for plane and solid figures. A plane figure is any part of a plane surface bounded by any number of straight or curved lines, or a combination of the two such as squares, rectangles, triangles, and circles. Plane figures have two dimensions—length and width. Solids such as cubes, prisms, cylinders, pyramids, spheres, and cones are bodies that have three dimensions—length, width, and thickness.

10-2. **Lines.** A *straight line* is the shortest line that can be drawn between two points. When the term "line" is used, it is understood to mean a straight line. A *curved line* is a line no part of which is straight. A *broken line* is made up of a series of straight lines or dashes. *Parallel lines* are lines in the same plane which will never meet, regardless of how far they are extended. All lines are measured in linear units and have only one dimension—length.

10-3. **Angles.** An angle is the amount of opening between two intersecting straight lines. The point of intersection of the two sides (lines), such as point B′ (pronounced B prime) in figure 6, is known as the *vertex*. Angles are measured in *degrees* (°), which can be further subdivided into minutes and seconds. Point B′ in figure 6 is the vertex of two 90° (right) angles. The sum of these two 90° angles is the straight line *AC*, which is equal to 180°.

10-4. A line is perpendicular to another line if it forms an angle of 90° with the other line. In figure 6, *BB′* is perpendicular to line *AC*.

10-5. **Plane Figures.** A plane figure is any part of a plane surface bounded by any number of straight or curved lines or combination of the two. When a plane figure is bounded by straight lines only, it is called a polygon. Polygons include figures with three, four, or more sides; however, it is customary to divide them into three classes. Those with three sides are triangles, those with four sides are quadrilaterals, and those with more than four sides are polygons. Plane figures bounded by a curved line include circles and ellipses.

10-6. *Triangles.* A triangle is a three-sided plane figure, such as that shown in figure 7. The sides of a triangle are the lines which bound or inclose it, and the sum of the included angles is always 180°. The base of a triangle is the side upon which it is supposed to stand; therefore, any side may be the base. The angle opposite the base is called the vertex angle, which is the point opposite to and farthest from the base. The altitude or height of a triangle is the perpendicu-

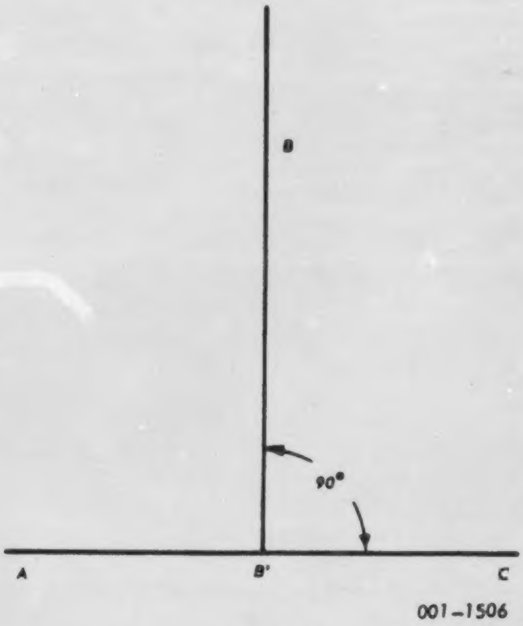


Figure 6. Perpendicular lines.

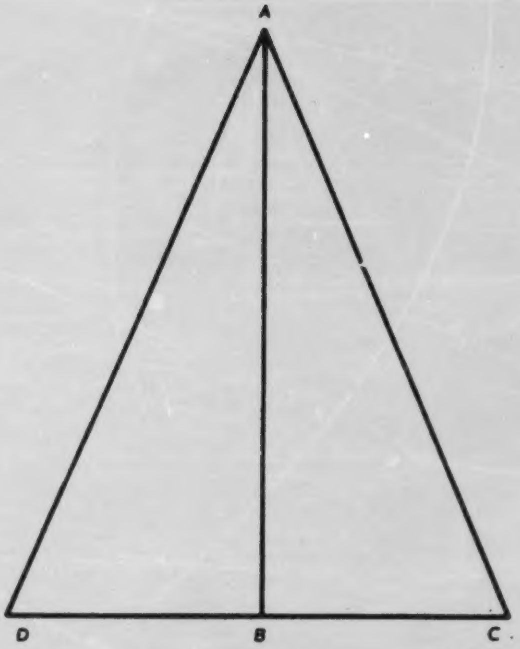


Figure 7. Isosceles triangle.

lar distance from the vertex to the base. In figure 7, A is the vertex angle, line DC is the base, lines AD and AC are the sides, and line AB is the altitude. The triangle illustrated in figure 7 is an *isosceles triangle*, in which two sides are equal, as shown by DAC. Side DA is equal to side AC. The unequal side (DC) of an isosceles triangle is usually called the base.

10-7. A *right triangle*, as shown in figure 8, is a triangle in which one of the angles is 90°. The side opposite the 90° angle is known as the hypotenuse, and the other two sides are called legs.

10-8. An *acute triangle*, as shown in figure 8, is one in which each angle of the triangle is less than 90°.

10-9. An *obtuse triangle*, as shown in figure 8, is a triangle in which one of the angles is more than 90°.

10-10. To find the *area of any triangle*, multiply the base times the height and divide by 2. *Example:* Find the area of a triangle which has a base of 24 inches and an altitude or height of 12 inches.

$$A = \frac{bh}{2}$$
$$A = \frac{24 \times 12}{2}$$
$$A = \frac{288}{2}$$
$$A = 144 \text{ square inches}$$

10-11. *Quadrilaterals.* We have already said that a quadrilateral is a plane figure with four sides. Now we introduce you to several types of quadrilaterals called parallelograms which have parallel and equal opposite sides. In figure 9 notice that the square, rectangle, rhomboid, and rhombus have parallel and equal opposite sides. *The altitude or height of a parallelogram is the perpendicular distance between two parallel sides.* Notice that in the rhomboid and the rhombus the altitude or height is indicated with a broken line. The trapezoid and the trapezium are also quadrilaterals but are not parallelograms.

10-12. The *square*, illustrated in figure 9, is a parallelogram with parallel sides that are equal and at right angles to each other. The broken diagonal line divides the square into two equal right triangles. The altitude or height of a square is the same as the sides. To determine the area of a square, multiply the length of one side by itself.

Example: If one side of a square is 15 inches, what is the area of the square?

$$A = s^2$$
$$A = 15 \times 15$$
$$A = 225 \text{ square inches}$$

10-13. The *rectangle*, illustrated in figure 9, is also a parallelogram with parallel opposite sides, equal opposite angles, and equal opposite sides. The broken diagonal line divides the rectangle into two equal right triangles. To find the area of a rectangle, multiply the base by the height.

Example: What is the area of a rectangle which is 8 inches wide and 6 inches high?

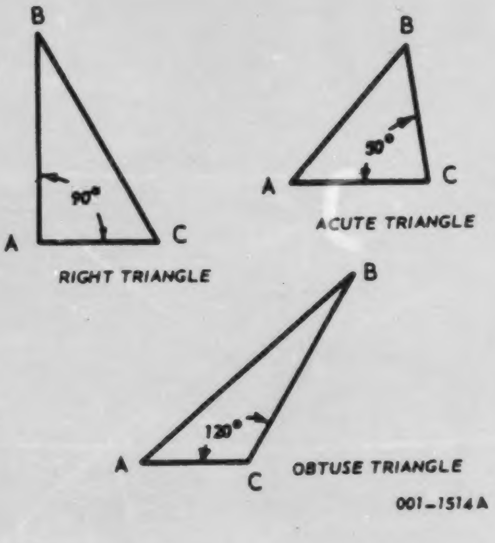
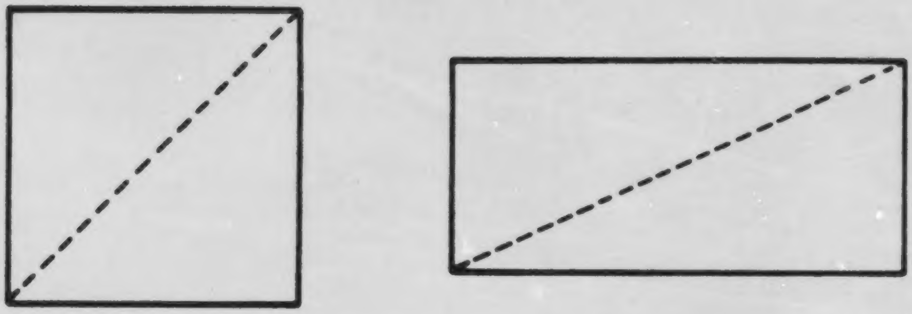
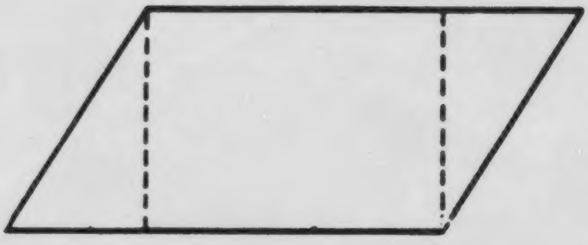


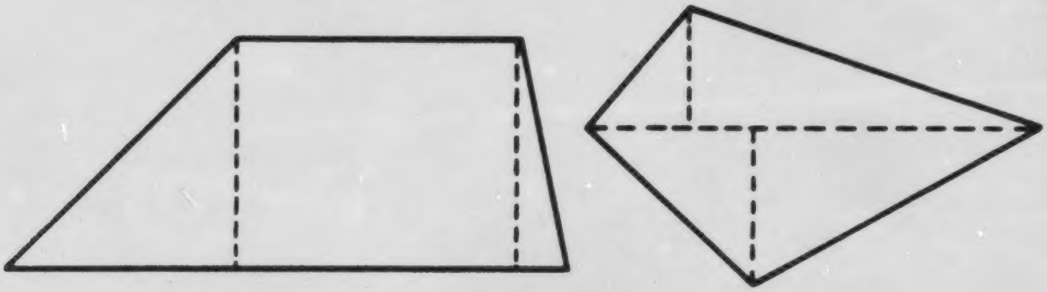
Figure 8. Triangles.



SQUARE RECTANGLE



RHOMBOID RHOMBUS



TRAPEZOID TRAPEZIUM

Figure 9. Quadrilaterals.

$A = bh$
$A = 8 \times 6$
$A = 48$ square inches

10-14. The *rhomboid*, illustrated in figure 9, is a parallelogram in which the opposite sides are parallel and equal and opposite angles are equal; however, there are no right angles as in the rectangle. The height or altitude is the perpendicular distance between two parallel sides as indicated by the broken lines. Notice in the illustration how a rhomboid can be divided into a rectangle and two right triangles. To find the area of a rhomboid, multiply the base by the height ($A = bh$).

10-15. The *rhombus*, illustrated in figure 9, is a parallelogram with parallel opposite sides which are equal in length and opposite angles which are equal. In the illustration the altitude, or height, is represented by the broken line. To find the area of a rhombus, multiply the base by the height ($A = bh$).

10-16. The *trapezoid*, shown in figure 9, is a quadrilateral with only two of the sides parallel; therefore, it is not a parallelogram. In the illustration the altitude or height is represented by the broken lines. To find the area of a trapezoid, take one-half the sum of the length of the parallel sides and multiply by the height.

Example: What is the area of a trapezoid that has a height of 12 inches and parallel sides that are 23 inches and 30 inches long?

$$A = \frac{(b + b')}{2} \times h$$

$$A = \frac{(23 + 30)}{2} \times 12$$

$$A = \frac{53 \times 12}{2}$$

$$A = \frac{636}{2}$$

$$A = 318 \text{ square inches}$$

10-17. The *trapezium*, illustrated in figure 9, is a quadrilateral without any parallel sides. Notice how the broken lines hare divided the trapezium into four triangles. To find the area of a trapezium or any other irregular polygon, divide it by means of diagonals into simpler forms, such as triangles. The areas of these parts may then be calculated by the rules given, and the sum of the various areas will be the total area of the figure.

10-18. *Polygons*. Although triangles and rectangles are polygons, they are not commonly called polygons, since we usually consider polygons to be figures with more than four sides. Some of the most common polygons you will encounter are illustrated in figure 10 and include the pentagon (five sides), the hexagon (six sides), the heptagon (seven sides), and the octagon (eight sides).

10-19. Polygons such as those shown in figure 10 have sides of equal length and are called regular polygons. If perpendicular lines are drawn to all sides of a regular polygon at the middle points, these perpendiculars will meet in a common point which is the center of the polygon. In sheet metalwork, it is sometimes necessary to make a pattern for a regular polygon. This is a simple process if you draw a circle the same size as the polygon, then draw the polygon inside the circle as shown in figure 11.

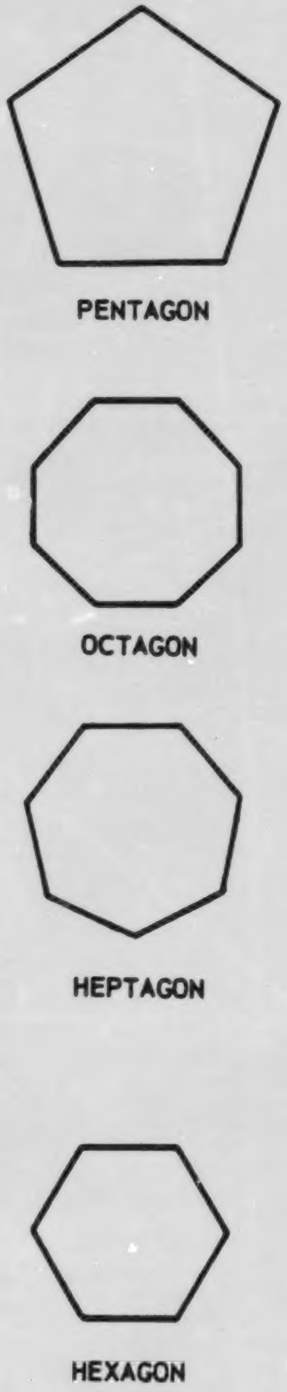


Figure 10. Regular polygons.

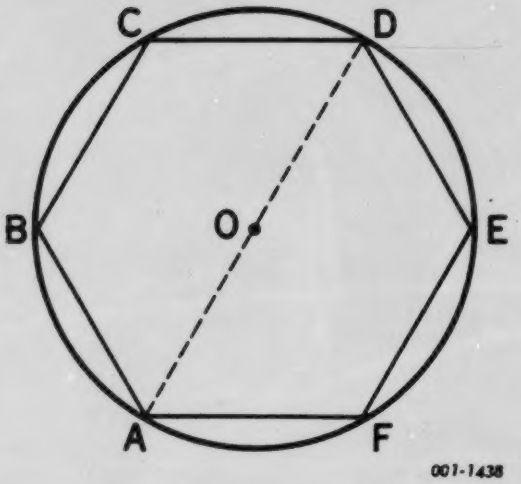


Figure 11. Hexagon inscribed in a circle.

10-20. The usual way to construct a regular polygon inside a circle is to divide the circumference of the circle into the same number of equal parts as the sides of the polygon. For example, in figure 11 a hexagon has been inscribed inside a circle. Any circle can be divided into the desired number of equal parts by stepping a compass around the circumference of a circle and adjusting the compass until a distance is found that produces the correct number of sides for the desired polygon. (Use of the compass is discussed in the following chapter.) In figure 11 the lines forming the sides of the hexagon, such as line *CD*, are called chords of the circle. Therefore, this method for constructing a regular polygon can also be used to divide a circle into equal parts and chords.

10-21. To save time in finding the exact length of the chords which divide a circle, the following constants are furnished. The distance between the points on the circumference of a circle can be found by multiplying the diameter of the circle by the constant (k) corresponding to the number of sides of the desired polygon. To divide a circle into equal chords, multiply the diameter by the appropriate constant (k) to find the length of one chord:

k for a pentagon $= 0.58779$
k for a hexagon $= 0.50000$
k for a heptagon $= 0.43388$
k for an octagon $= 0.38268$

Example: Construct a hexagon, similar to the one shown in figure 11, with a diagonal of 3 inches. First, construct a circle with a 3-inch diameter; then use the constant for a six-sided polygon and find the chord length. $3 \times 0.50000 = 1.50000$ inches will be the length of each of the six chords. Now, adjust the compass to a spread of 1½ inches, step the compass around the circle, and mark off six equidistant points. Use a straightedge and draw chord lines between the six points. The resulting figure will be like the one shown in figure 11.

10-22. A simple way to find the area of a regular polygon is to square the length of a side and multiply by a constant (k) corresponding to the number of sides. The constants for common polygons are as follows: $k = 1.7205$ for a pentagon; $k = 2.5981$ for a hexagon; $k = 3.6339$ for a heptagon; and $k = 4.8284$ for an octagon. *Example:* What is the area of an octagon with 4-inch sides?

$$A = s^2\ k$$
$$A = s^2 \times 4.8284$$
$$A = 16 \times 4.8284$$
$$A = 77.2544 \text{ square inches}$$

10-23. To find the area of an irregular polygon (polygon whose sides are not all equal), it can generally be divided by means of diagnonals into simpler forms such as triangles and squares. The areas of these parts can then be calculated, and the sum of the various areas will be the total area of the irregular polygon.

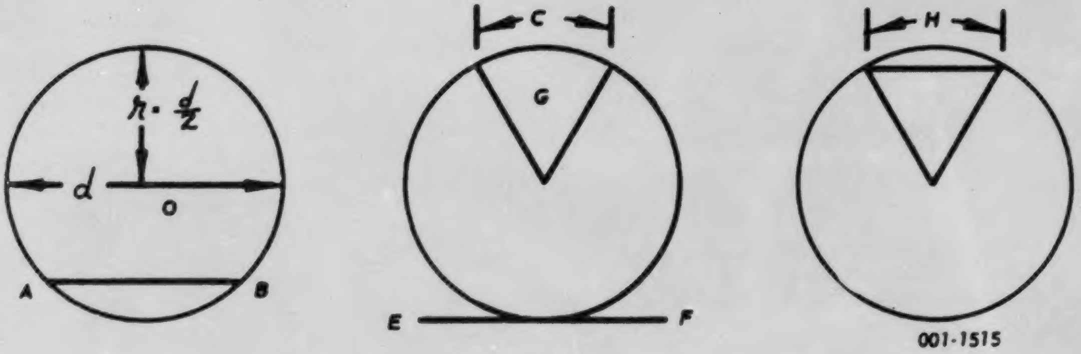


Figure 12. Parts of a circle.

10-24. *Circles.* A circle is a plane figure bounded by a curved line called the circumference. All points on the circumference are equidistant from the center. Figure 12 illustrates the lines and parts of circles.

10-25. The *circumference* of a circle is the length of the curved line which forms the circle; it may be referred to as the perimeter of a circle. Generally speaking, the letter C is used to designate circumference in a formula. The circumference of any circle is divided into 360 equal units of measurement called degrees (360°); however, in sheet metalwork we most often use linear measurements, such as inches and feet. When figuring the circumference of a circle, you will use the predetermined number 3.1416, called pi (π), which is the ratio of the distance around the perimeter of the circle to the diameter of the circle. The circumference of a circle can be found by multiplying the diameter by pi.

Example: What is the circumference of a circle that has a diameter of 5 inches?

$$C = \pi d$$
$$C = 3.1416 \times 5$$
$$C = 15.7080 \text{ inches}$$

10-26. The *diameter* of a circle is a line drawn through the center and ended by the circumference. The letter d, shown in figure 12, is used to identify the diameter. The diameter of a circle can be found by dividing pi (3.1416) into the circumference.

Example: What is the diameter of a circle that has a circumference of 18.8496 inches? $C = \ d$, then:

$$d = \frac{C}{\pi}$$
$$d = \frac{18.8496}{3.1416}$$
$$d = 6 \text{ inches}$$

10-27. The *radius* of a circle is one-half the diameter $\left(\frac{d}{2}\right)$ or the distance from the center to a point on the circumference. The letter r, shown in figure 12, is used to identify the radius, then $r^2 = \frac{d^2}{4}$.

10-28. The *area* of a circle can be determined by two formulas. If r is known, square the radius and multiply by π $(A = \pi r^2)$. If d is known, then use $A = \frac{\pi d^2}{4} = \frac{3.1416d^2}{4} = 0.7854d^2$; or square the diameter and multiply by the number 0.7854, since $\frac{\pi}{4} = 0.7854$, a constant (k). Either way is correct.

Examples: What is the area of a circle that has a radius of 2 inches? What is the area of a circle having a diameter of 4 inches?

a. $A = \pi r^2$
$A = 3.1416 \times 2 \times 2$
$A = 12.5664$ square inches

b. $A = \frac{\pi d^2}{4} = d^2k$
$A = d^2 \times 0.7854$
$A = 16 \times 0.7854$
$A = 12.5664$ square inches

10-29. An *arc* is any part of the circumference of a circle, such as C and H in figure 12. Letters or numbers may be used to identify various arcs. A major arc is larger than a semicircle, and a minor arc is less than a semicircle.

10-30. A *chord* is a straight line joining any two points on a circle or an arc, as shown by AB in figure 12. Whenever one chord is drawn within a given circle, it forms two arcs—a major arc and a minor arc.

10-31. A *tangent* is a straight line drawn in such a manner that it touches only a single point of the circumference of a circle. Line EF in figure 12 is tangent to the circle.

10-32. A *sector* of a circle is that part bounded by two radii and an arc. In figure 12 the letter G is used to identify the sector of a circle bounded by the arc C.

10-33. A *segment* of a circle is that part which is bounded by an arc and a chord connecting the ends of the arc. In figure 12 the letter H identifies a segment.

10-34. **Solids.** A solid is any surface or a series of surfaces which incloses a section of space such as a cube, sphere, or cylinder. All solids have length, thickness, and width; and the space within the solid is called volume. Because of the three dimensions of solids, volume is identified as cubic inches, cubic feet, etc. (This differs from the plane figures, studied in the previous paragraphs, which had only two dimensions, and the space they contained was identified as area in square inches, square feet, etc.)

10-35. *Prisms.* A prism such as that shown in figure 13 is a solid whose ends are equal parallel polygons and whose sides (faces) are parallelograms. Remember that polygons, as well as parallelograms, can have several shapes. Therefore, you will find that prisms can be of various shapes and still comply with the definition. For example, figure 13 illustrates a rectangular prism. Others include triangular prisms whose ends are triangles, hexagonal prisms whose ends are hexagons, etc.

10-36. The *rectangular prism* shown in figure 13 has ends (bases) that are square; however, rectangular prisms may also have ends of other rectangular shapes if all angles are right angles and the opposite surfaces are parallel: To determine the volume of a rectangular prism, simply multiply the length times the width times the thickness ($V = lwt$). For example, if a rectangular

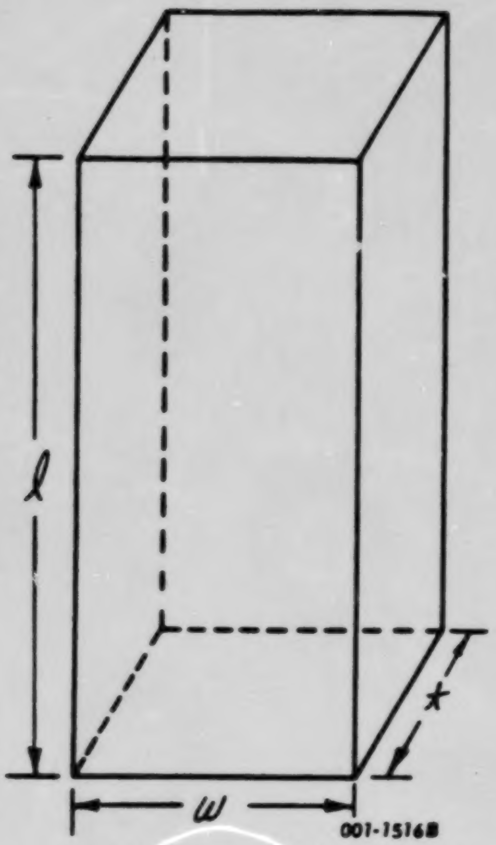


Figure 13. Rectangular prism.

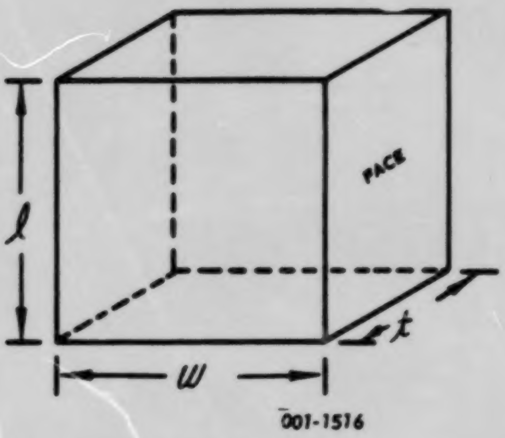


Figure 14. Cube.

prism has the dimensions of $l = 10$ inches, $w = 5$ inches, and $t = 5$ inches, the volume will be $10 \times 5 \times 5 = 250$ cubic inches.

10-37. The *cube* shown in figure 14 is a rectangular prism whose ends and faces are squares. Stated in another way, a cube is a solid object with all sides equal. The volume of a cube can be determined by the same formula that you have learned for rectangular prisms; however, since all sides of a cube are the same, the formula $V = lwt$ can be shortened to simply $V = s^3$. For example, if the length of one side of a cube is 4 inches, then the volume can be computed as $4 \times 4 \times 4 = 64$ cubic inches.

10-38. *Cylinder.* A cylinder is a solid figure bounded by a lateral curved surface with round ends or bases equal in size. The end on which the cylinder is shown to rest in figure 15 is called the base, and the distance between the two ends is called the altitude or height.

10-39. The volume of a cylinder can be determined by multiplying the area of the base times the height ($V = A_bh$). Notice that you must know the area (A_b) before solving for the volume. In previous paragraphs of this chapter you learned how to figure the area of a circle. Since the ends of a cylinder are circles, the same formula(s) applies; therefore, we can change the formula $V = A_bh$ to $V = r_2h = 0.7854\ d_2h$.

Example: Assume that a cylinder has a diameter of 2 inches and a height of 10 inches. What is the volume?

$$V = kd^2h$$
$$V = 0.7854\ d^2h.$$
$$V = 0.7854 \times 2^2 \times 10$$
$$V = 0.7854 \times 4 \times 10$$
$$V = 31.416 \text{ cubic inches}$$

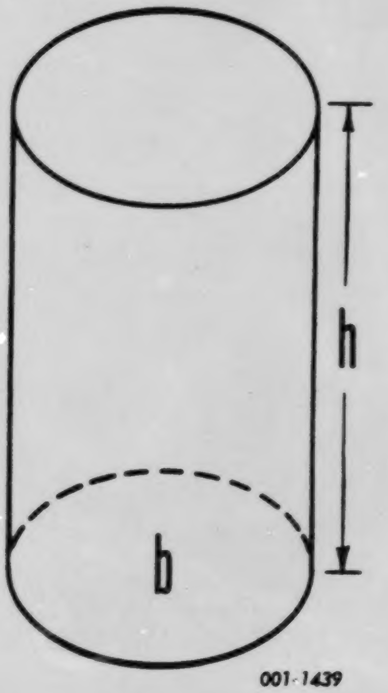


Figure 15. Cylinder.

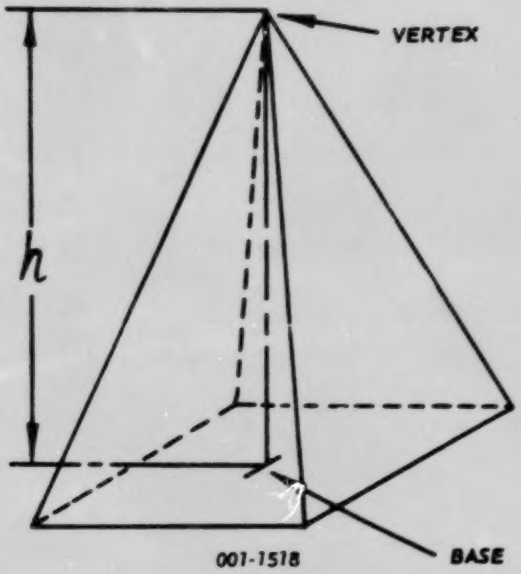


Figure 16. Pyramid.

10-40. The curved area of a cylinder (area of the outside surface not including the base) can be determined by multiplying the circumference of the base by the height of the cylinder.
Example: Assume that the cylinder illustrated in figure 15 has a diameter of 2 inches and a height of 10 inches. What is the curved area?

$$A = Ch$$
$$A = \pi d \times h \qquad (C = \pi d)$$
$$A = 3.1416 \times 2 \times 10$$
$$A = 62.832 \text{ square inches}$$

10-41. *Pyramid.* A pyramid is a solid figure whose base may be a plane triangle, rectangle, or other polygon. Its sides form several triangles with a common vertex. The pyramid shown in figure 16 is a right pyramid, because a perpendicular line from the vertex to the base passes through the center of the base.

10-42. The volume of a right pyramid, as shown in figure 16, can be determined by multiplying the area of the base (A_b) by one-third its height.
Example: What is the volume of a pyramid that is 18 inches high and has a base 12 inches square?

$$V = \tfrac{1}{3}h \times A_b$$
$$V = \tfrac{1}{3} \times 18 \times 12^2$$
$$V = \tfrac{1}{3} \times 18 \times 144$$
$$V = 864 \text{ cubic inches}$$

10-43. The surface area of a pyramid (area of the outside surface not including the base) can be determined by multiplying the perimeter (P) of the base by one-half of the slant height. The slant height of a pyramid is the same as the altitude of any one of the triangular faces of the pyramid.
Example: What is the surface area of a pyramid that has a slant height of 20 inches and has a base 12 inches square?

$$A = \tfrac{1}{2}h_s \times P$$
$$A = \tfrac{1}{2} \times 20 \times 48$$
$$A = 480 \text{ square inches}$$

10-44. *Cone.* A cone is a solid figure attained when a right triangle is rotated about one of its legs. This leg is commonly referred to as the axis. The base of the cone is the circle formed when the horizontal leg is rotated completely around the axis, as shown in figure 17.

10-45. The volume of a cone can be found by multiplying the area of the base (A_b) by one-third of the height.
Example: What is the volume of a cone that is 9 inches high and has a diameter of 6 inches?

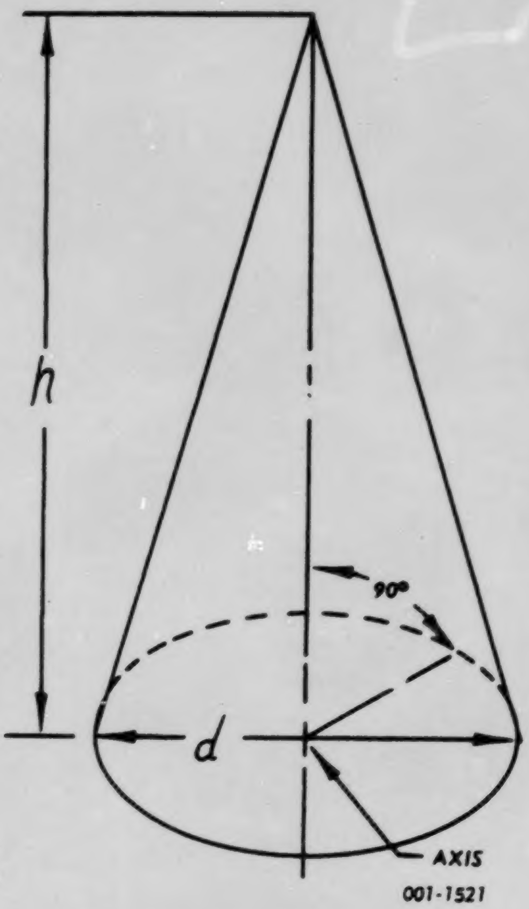


Figure 17. Cone.

$V = \frac{1}{3}h \times A_b$
$V = \frac{1}{3}\,hkd^2$
$V = \frac{1}{3} \times 9 \times 0.7854 \times d^2 \; (A_b = 0.7854 \times d^2)$
$V = \frac{1}{3} \times 9 \times 0.7854 \times 36$
$V = 84.8$ cubic inches

10-46. The curved area of a cone (area of the outside surface not including the base) can be determined by multiplying the circumference of the base by one-half the slant height.
Example: What is the curved area of a cone that has a circumference of 16 inches and a slant height of 10 inches?

$A = \frac{1}{2}h_s \times C$
$A = \frac{1}{2} \times 10 \times 16$
$A = 80$ square inches

10-47. *Sphere.* A sphere is a ball-shaped solid figure bounded by a uniformly curved surface, every point of which is equidistant from the center.

10-48. The volume of a sphere is the cube of the diameter multiplied by the constant *k* or 0.5236.

$$V_s = \frac{4\pi r^3}{3} = \frac{4}{3}\,\frac{\pi d^3}{8} = 0.5236d^3$$

Example: What is the volume of a sphere that has a diameter of 2 inches?

$V = d^3k$
$V = d^3 \times 0.5236$
$V = 2^3 \times 0.5236$
$V = 2 \times 2 \times 2 \times 0.5236$
$V = 4.1888$ cubic inches

10-49. The surface area of a sphere is the square of the diameter multiplied by pi.

$$A_s = 4\pi r^2 = \frac{4\pi d^2}{4} = \pi d^2$$

Example: What is the surface area of a sphere with a diameter of 2 feet?

$A_s = \pi d^2$
$A_s = 3.1416 \times 2^2$
$A_s = 3.1416 \times 4$
$A_s = 12.5664$ square feet

29

Measurement and Layout Tools

ALL SHEET metalwork requires accurate measurement and layout techniques, and this chapter has been prepared to help you learn about the tools used in measurement and layout operations. Your specialty description states that as a sheet metal specialist you will take measurements from drawings and lay out working details for fabrication of sheet metal items. Your specialty training standard contains a list of the tools you must learn to use. The information you learned in the previous chapter concerning graduated scales; how to work with fractions and decimal numbers; and how to use formulas to determine size, area, and volume of geometric figures will be used in the following discussions of measurement and layout tools.

2. In this chapter, you will learn how to use measuring tools, such as rules, tapes, combination sets, squares, calipers, and micrometers. And you will learn how to use layout tools, such as levels, architect's scales, compasses, dividers, T-squares, triangles, protractors, templates, irregular curves, trammel points, plumb lines, and chalk lines.

3. Each measurement and layout tool has special uses in sheet metalwork. For example, rules and tapes are used for measuring sheet metal which is to be cut or folded, or for the measuring of parts to be duplicated. Another example is the compass, which can be used to draw a polygon inside a circle or to perform graphic solutions to problems. Still another example is the scriber which can be used to scribe or mark a line to indicate where a sheet of metal is to be cut. From these examples, you can see that each measurement and layout tool has specific uses; we will discuss separately how each applies to your job. Since you have already learned how to read graduated scales, it is logical to begin with measuring tools.

11. Measuring Tools

11-1. In this section, we will discuss the measuring tools which you will use in the fabrication, repair, and installation of sheet metal parts.

11-2. **Rules.** The term "rule" is accepted as a general term used to describe a great number of measuring devices. More specifically, a rule is a strip of wood, metal, or other suitable material made in standard lengths and is marked along one or more edges into specified parts, divisions, or units of measure. The English system of linear measure, of which inches and feet are units of length, is used for measuring sheet metal. As you learned in Chapter 2, the inch may be divided into smaller parts by means of either common or decimal fractional divisions. The fractional divisions for an inch are found by dividing the inch into equal parts—the more common ones are halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. Fractions of an inch are also expressed in decimals, called equivalents of an inch. For example, ⅛" = 0.125", ¼" = 0.250", ½" = 0.500", etc.

11-3. At home and at school you have learned to use common wood or plastic rulers which were 6, 12, or 15 inches long, with subdivisions down to sixty-fourths of an inch. Probably you are also familiar with the common yardstick, which is 3 feet long and has subdivisions down to eighths of an inch.

11-4. *Steel rules.* Steel rules are available in 6-, 12-, and 15-inch lengths and may be rigid or flexible. You will frequently use the 6-inch steel rule, which easily fits in a shirt pocket and is semiflexible. It may have information on the back side, such as a decimal equivalent scale. To measure with a steel rule, use it as shown in figure 18. You will be using several layout and measuring devices which incorporate a rigid steel rule, such as the combination set, framing square, and circumference rule. These are discussed later in this chapter.

11-5. *Folding rule.* The folding rule shown in figure 19 is typical of this kind of rule, which unfolds to 6 feet and is graduated in sixteenths of an inch. Folding rules are usually made of wood, have brass tips called striking plates, and have

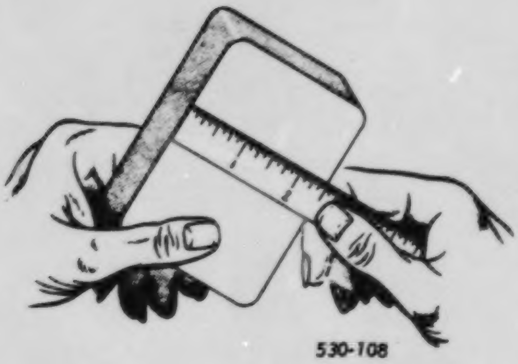


Figure 18. Using a 6-inch steel rule.

positive locking joints also made of brass. Although these rules are principally used by carpenters, sheet metal specialists also find them handy and easy to use.

11-6. *Circumference rule*. The circumference rule shown in figure 20 provides a "shortcut" method for computing the circumference of a circle. This rule is available in 36- and 48-inch lengths. The upper edge is graduated in inches in the same manner as a regular steel rule, but the lower edge is graduated quite differently. The lower edge will give you the approximate circumference of any circle within the range of the rule. The circumference scale is equivalent to the diameter times 3.1416. From Chapter 2, you remember the formula for finding the circumference of a circle ($C = \pi d$). Notice in figure 20 that the reading on the lower edge directly below the 3-inch mark is a little less than 9½ inches. This reading is the approximate circumference of a circle with a diameter of 3 inches. When using this rule, place the lower edge exactly on the center of the circle, and measure the distance across the circle just as if a diameter line were drawn.

11-7. **Steel Tapes.** Steel measuring tapes are available in lengths from 6 feet to 100 feet and are contained in various shapes of hand-held cases. These easy-to-wind tapes are flexible and are wound around a reel with a small handcrank or by a spring inside the reel case. Two kinds of measurements are made with steel tapes, inside measurements and outside measurements. For a simple explanation, think of a wooden box with no top. An inside measurement is made by putting the tape down inside the box and measuring the distance from one side to the opposite side. An outside measurement is made by measuring the external dimensions of the box such as the height or width. Some steel tapes are designed to make both inside and outside measurements.

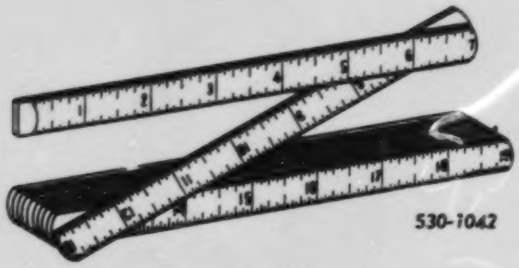


Figure 19. Folding rule.

11-8. The 25-foot steel measuring tape shown in figure 21 is graduated in eighths of an inch and is wound into the case by the hinged handcrank. This type of case is also used for 50-, 75-, and 100-foot tapes. In sheet metalwork, you will find these longer tapes useful to measure such items as long ducts, gutters, gravel guards, and metal roofs. The 25-foot and longer tapes are best suited for making outside measurements; however, inside measurements are possible. When using one of these longer tapes for outside measurements, be sure to examine the hook or ring on the end of the tape for the actual point of beginning. Since measuring tapes are available with a variety of ends such as hooks, rings, or a combination of both, it is possible to make a measurement error of approximately 1/16 inch. The inch and foot graduations printed on the tape are measured from the *outside* of the ring which is the actual end of the tape. When measuring from a point not at the actual end of the tape, such as with the ring hooked on a nail, a correction equal to the thickness of the ring must be figured into the readout measurement.

11-9. The steel tape you will most frequently use is the pocket size power-return tape shown in figures 22 and 23. The tape case contains an internal spring that returns the tape when measuring is completed. This flexible tape has a slight curvature that causes it to be stiffened when extended; this is a good feature, because it allows the tape to be extended straight out of the case. Power-return steel tapes are available in 6-, 8-, 10-, and 12-foot lengths; however, you will prob-

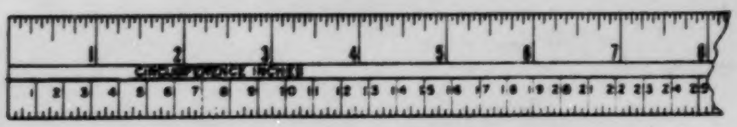


Figure 20. Circumference rule.

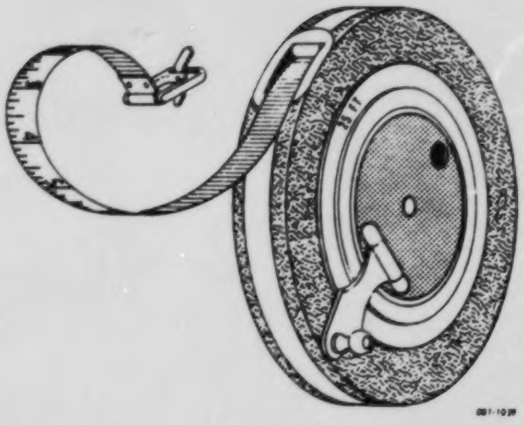


Figure 21. 25-foot steel measuring tape.

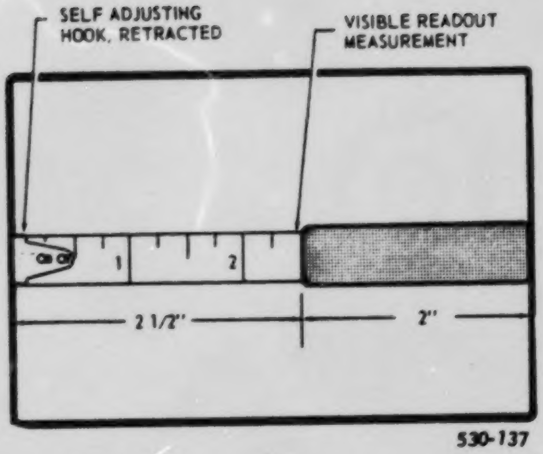

SELF ADJUSTING
HOOK, RETRACTED
VISIBLE READOUT
MEASUREMENT
1
2
2 1/2"
2"
530-137

Figure 22. Making inside measurements with a power-return steel tape.

ably prefer the 8-foot length. These tapes are graduated in sixteenths and thirty-seconds of an inch and are designed for both inside and outside measuring. Each tape has a self-adjusting hook that automatically compensates for the thickness of itself. Thus you do not have to figure in a correction when making measurements. The case is specially designed for making inside measurements. Since it is 2 inches long, when making inside measurements, the 2 inches are simply added to the visible readout, as shown in figure 22. The visible readout when making inside measurements is the number of inches or feet from the end of the tape to the index point at the case. For example, an *inside* measurement of a box might show a readout of 2½ inches, which added to the 2 inches for the tape case would be a total inside measurement of 4½ inches. An example of an *outside* measurement is illustrated in figure 23. Notice that the self-adjusting hook is extended, and the readout measurement is the inches or feet at the exact edge of the surface.

11-10. **Combination Set.** The combination set shown in figure 24 is, as its name indicates, a tool that has several uses. It consists of a rigid steel rule, called the blade, and three attachments—the square and miter head, the turret protractor head, and the center head. Although the illustration shows all three attachments installed on the blade, they are used individually. During use only one attachment will be on the blade.

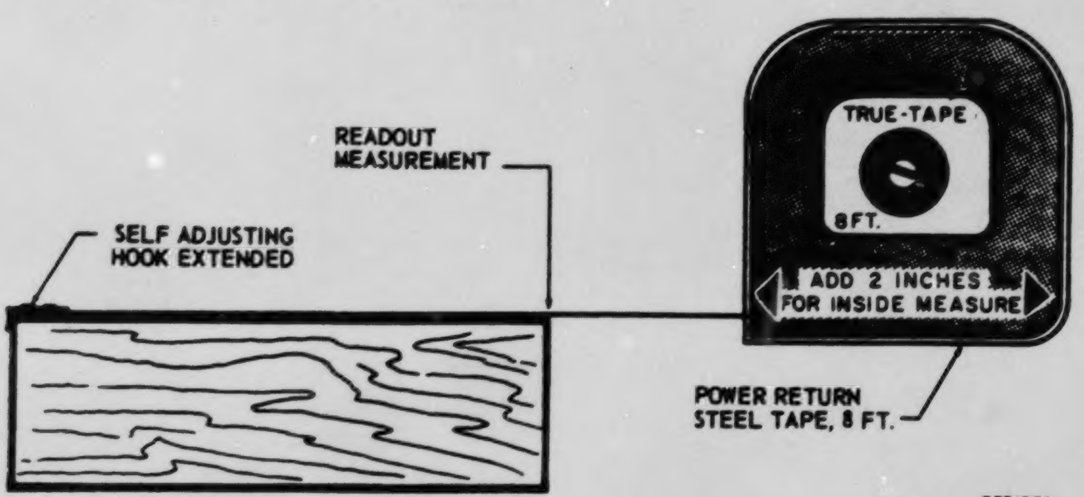

READOUT
MEASUREMENT
SELF ADJUSTING
HOOK EXTENDED
TRUE-TAPE
8FT.
ADD 2 INCHES
FOR INSIDE MEASURE
POWER RETURN
STEEL TAPE, 8 FT.
530-138

Figure 23. Making outside measurements with a power-return steel tape.

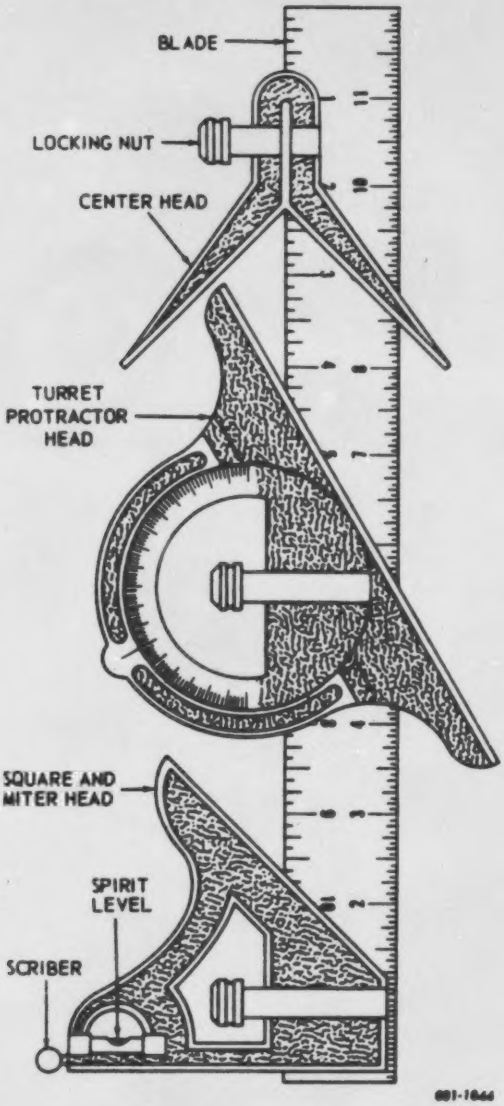


Figure 24. Combination set.

11-11. The blade has a central groove to permit the attachments to be moved to any desired setting and locked in that position. The central groove is not visible in figure 24, as it is located on the reverse side of the blade illustrated; however, in figure 25 the central groove is shown in each view of the blade. The steel blade is usually graduated in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch; it may be pulled out of the attachments and used as a measuring rule if desired.

11-12. When only the square and miter head is installed on a blade, it is called a combination square, since the head has 90° and 45° angles. Figure 25 shows several uses of the combination square. In each of these the square and miter head has been moved to the desired position on the blade and locked at that position with the locking nut. Another convenient feature of the square and miter head is the spirit level, since it is often necessary to square one piece with another and at the same time tell whether one or the other is level or plumb. Or, if desired, the square and miter head can be used as a simple level. As a further convenience, a small scriber is contained in the square and miter head. It is easily removed for use in marking (scribing) lines on metal.

11-13. The center head, shown in figure 24 and 25, can be used to scribe a line through the center of a circular object or to measure the diameter. Notice how one edge of the blade bisects the angle of the center head.

11-14. The turret protractor head, shown in figure 24, is graduated in 360° and can be used to determine the number of degrees in an unknown angle, to construct angles of known degrees, or to transfer and lay out identical angles. In sheet metalworking terminology, the words "angle" and "bevel" are often used interchangeably. For example, a long section of gravel guard, for the edge of a flat roof, will have a V-shaped groove for a stiffener. When making the angles of this groove on a cornice brake, you may hear them referred to as angles or bevels. The turret protractor can be used to duplicate bevels such as these V-shaped grooves of gravel guards.

11-15. **Framing Square.** The steel framing square shown in figure 26 is often used in sheet metalwork. It is also known as a rafter square and a carpenter's square; however, in your shop it will most likely be called a square. Although it has many specialized uses and is available with various graduations, its principal value to you is in making layouts, for checking the squareness of corners, for measuring distances under 24 inches, and for determining the pitch of roofs. In figure 26, you can see the parts of the framing square—the body, which is usually 24 inches long and 2 inches wide; the tongue, which is usually 16 inches long and 1½ inches wide; and the 90° heel. One side of the square is called the face and the other side the back. It is common for the face to be graduated in eighths and sixteenths of an inch and the back to be graduated in tenths and twelfths of an inch.

11-16. One of the jobs of a sheet metal specialist is to fabricate and replace roof jacks. A roof jack as shown in figure 27 is a cylinder made of sheet metal which you may have previously called a chimney, stove pipe, or stack. The lower end of the roof jack is cut to the same angle as the slope

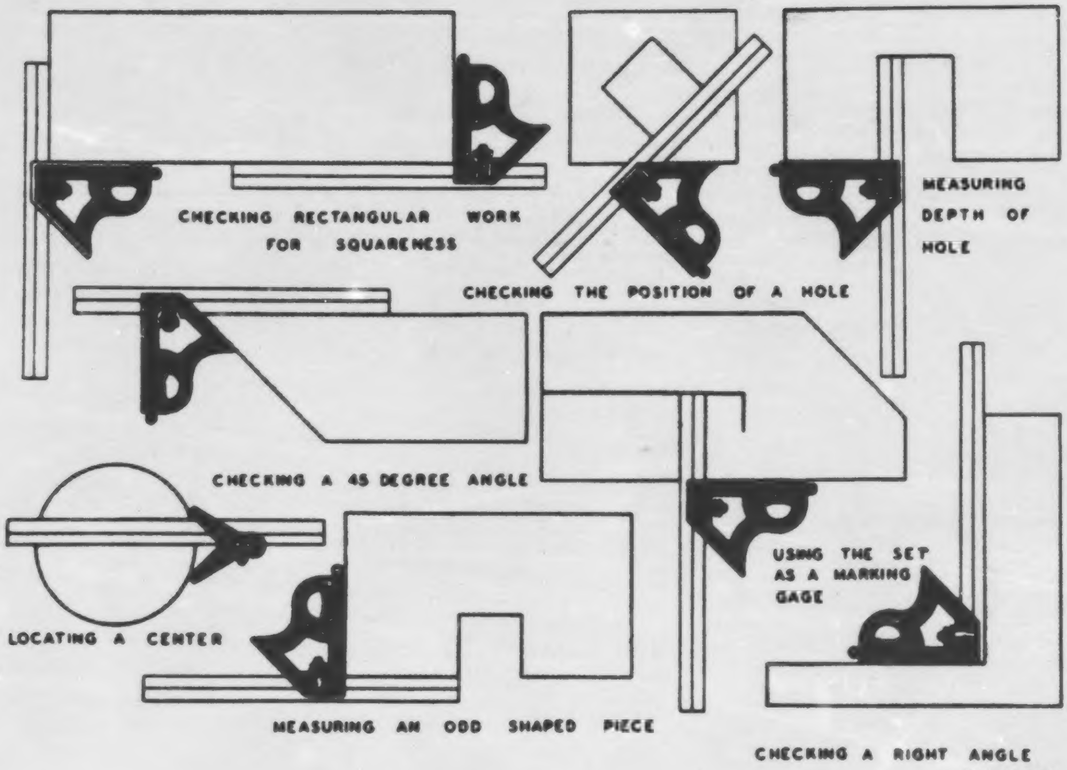

CHECKING RECTANGULAR WORK FOR SQUARENESS
CHECKING THE POSITION OF A HOLE
MEASURING DEPTH OF HOLE
CHECKING A 45 DEGREE ANGLE
LOCATING A CENTER
USING THE SET AS A MARKING GAGE
MEASURING AN ODD SHAPED PIECE
CHECKING A RIGHT ANGLE
001-1044A

Figure 25. Several uses of the combination set.

(pitch) of the roof. This lower end is fastened to a square sheet of metal called the base. Now cutting the roof jack to the same pitch as the roof is important if it is to stand erect without leaning. Thus, your problem is to determine the pitch of the roof, which will also be the angle to make the roof jack. One of the ways to determine the pitch of the roof is to use a framing square and a level, as shown in figure 27. The body of the square is leveled and the 12-inch mark placed on the roof line. The reading on the tongue will be the drop in 12 inches. In the illustration, the roof line passes through the 5-inch mark on the tongue of the square, which indicates that the roof drops 5 inches every 12 inches. These two figures are significant, because in this example the pitch of the roof is 5–12. (This can also be expressed as a 5-foot drop in 12 feet.) For the purposes of making the roof jack, the square can also be used to make the pattern with the corresponding 5–12 pitch. After the roof jack has been fabricated, the framing square can be used to verify that the pitch is 5–12, or whatever the desired pitch may be.

11-17. Another use of the square is for finding the opposite point on the circumference of a circle. This method is useful when locating holes for round duct dampers, placing ears on pails, etc. In figure 28 assume that we want to find a point opposite point A. With the tongue of a square located on point A and the heel placed at any other point on the circumference, such as point C, the body will cross the circle at point B, which is directly opposite point A. A second example, illustrated by the dashed lines, shows that the heel of the square can be located at any convenient point on the circumference of the circle.

11-18. **Calipers.** Calipers are used for measuring diameters and distances and for comparing distances and sizes. The three common types include outside calipers, inside calipers, and hermaphrodite calpers. None of these are recommended for precision measurements that involve measurements of less than $^{1}/_{64}$ inch.

11-19. *Outside calipers.* Outside calipers are used for measuring outside dimensions, as shown in figure 29. The illustration shows how the outside caliper can be used to measure diameters such as the diameter of round stock; it also shows how the caliper can be set to a desired measurement and the stock checked for conformance with specifications. When using an outside caliper,

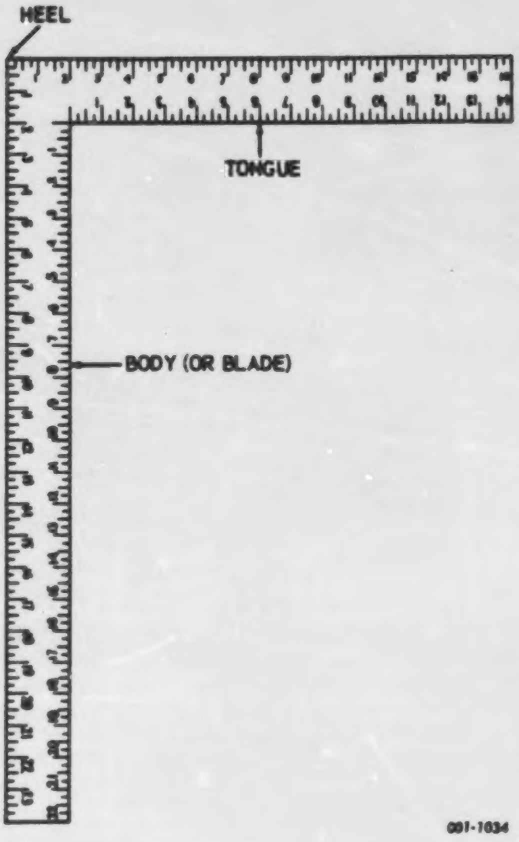


Figure 26. Framing square.

you should be careful to hold the legs at right angles to the object being measured in order to prevent errors in measurement.

11-20. *Inside calipers.* The inside calipers, shown in figure 30, have curved legs for measuring inside diameters of holes, the distances between two surfaces, the width of slots, and other similar jobs. Notice how the legs of the inside calipers differ from the legs of outside calipers. The illustration shows how inside calipers should be held at right angles to the cylinder being measured. If held in the position labeled "wrong," the measurement will *not* be correct. Inside calipers may be used to measure distances or to check an opening for a specified size.

11-21. *Hermaphrodite calipers.* The hermaphrodite caliper, shown in figure 31, has legs that are different from each other. Notice that one leg can be used for outside measurement and the other for inside measurement as well as for scribing. Although these calipers can be used for scribing arcs, as shown in the illustration, you will find them most useful as a marking gage.

11-22. **Micrometers.** The smallest measurement normally which can be made with a steel rule and calipers is $\frac{1}{64}$ inch; therefore, to measure smaller distances, a micrometer is used. The two main types of micrometers are plain and vernier. The main difference between these two types is that the vernier micrometer has an additional decimal scale called the vernier scale. Each micrometer is available in several sizes and variations, such as inside and outside micrometers. An

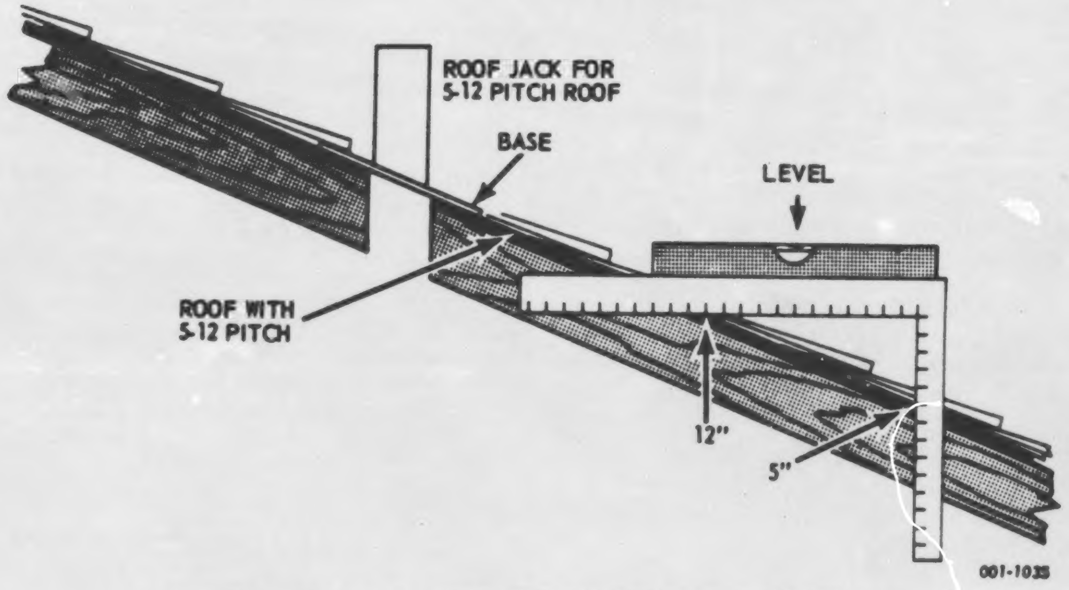


Figure 27. Measuring pitch of roof with framing square and level.

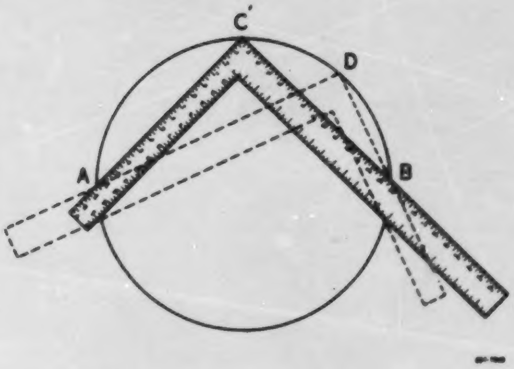


Figure 28. Locating the opposite side of a circle with a square.

outside micrometer is shown in figure 32 as it is being used to measure the thickness of a piece of sheet metal. The scales of micrometers are calibrated in decimal fractions; if you have a dimension given in a common fraction, it must first be converted to the decimal equivalent.

11-23. In Chapter 2, you learned that the decimal system is another method of expressing fractions and mixed numbers. Remember all figures to the left of the decimal point are whole numbers and all figures to the right of it indicate parts of whole numbers; for example, 3 inches is written as 3.000. When there is no number to the left of the decimal point, the quantity is less than one as in 0.010. Starting from the decimal point and moving to the right, the first digit indicates tenths; the second, hundredths; the third, thousandths; the fourth, ten-thousandths; and so on. The decimal fractions from plain micrometers are usually read in thousandths such as 0.100, 0.250, and 0.375. The decimal fractions from vernier micrometers are usually read in ten-thousandths such as 0.1000, 0.0250, and 0.2575.

11-24. *Parts of a micrometer.* The principal parts of the micrometer shown in figure 33 are the frame, barrel, and anvil (fixed parts), and the thimble and spindle (movable parts). The thimble rotates the spindle, which moves in the threaded portion inside the barrel. Turning the thimble provides an opening between the anvil and the spindle, where the object is measured. The size of the object is indicated by the graduations on the barrel and thimble.

11-25. *Reading a micrometer.* The stationary barrel is divided into 10 equal divisions, numbered 1 through 10, each representing 100/1000 or 0.100 inch, 0.200 inch, 0.300 inch, etc., as shown in figure 34. Each division is subdivided into four equal parts of 0.025 inch each. One complete turn (revolution) of the thimble, from zero on the thimble around to the same zero, moves it one of these subdivisions (0.025 inch) along the barrel.

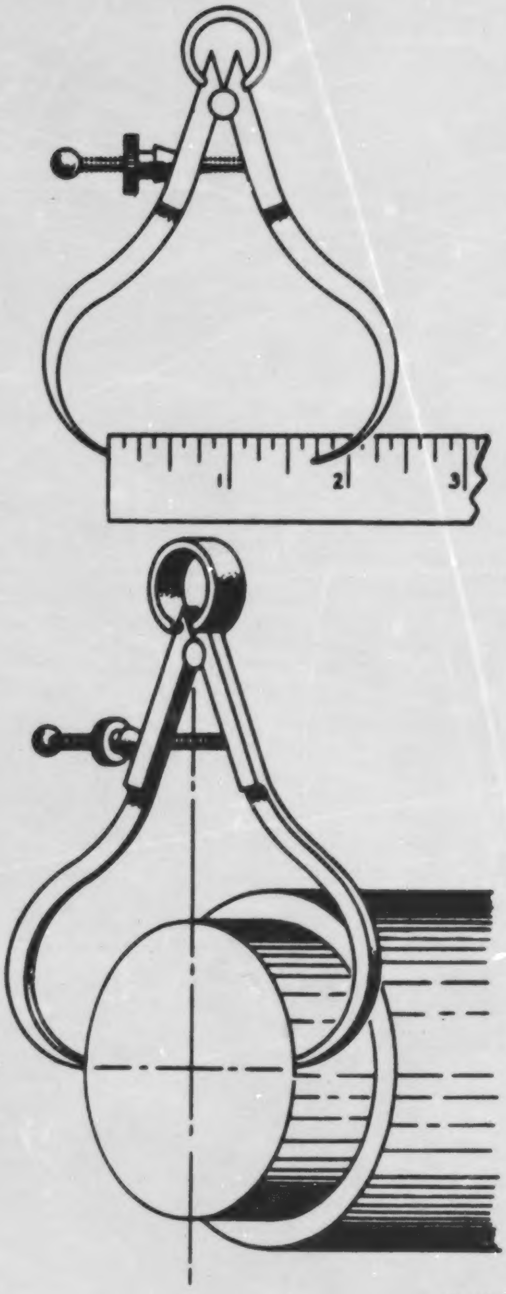


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Figure 29. Using an outside caliper.

11-26. The beveled edge of the thimble is divided into 25 equal parts, and each part represents $\frac{1}{25}$ the distance the thimble travels along the barrel in moving from one of the 0.025-inch

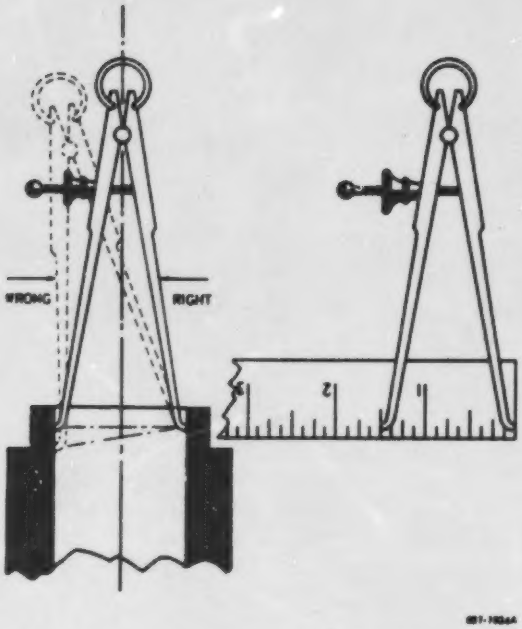

Figure 30. Using an inside caliper.

horizontal subdivisions to another. Thus, each mark or division on the thimble represents $^{1}/_{1000}$ (0.001) inch. For convenience, these divisions are numbered every fifth mark by 0, 5, 10, 15, and 20. When 25 of these graduations have passed the horizontal line on the barrel, the thimble will have made one revolution and the spindle will have moved 0.025 inch.

11-27. To read the micrometer shown in figure 34, look for the last (highest) number that is exposed on the barrel. In the illustration it is the number 2, which is equal to 0.2 inch but is read in thousandths or 0.200 inch ($^{200}/_{1000}$ inch). Next, count the marks on the barrel to the right of the number 2. In the illustration you can see three marks, each of which is equal to 0.025 inch or a total of 0.075, which is added to the first reading of 0.200 (0.200 + 0.075). This makes a total of 0.275. Next add the decimal value indicated by the thimble (which in this case is 25), since the thimble has been turned a complete revolution past the third mark to the right of the number 2 on the barrel. This 25 represents 0.025 inch, which is added to the other two readings to give the final value of 0.300 inch (0.200 + 0.075 + 0.025 = 0.300). This is read as $^{300}/_{1000}$. In this example, we could have taken a short cut and combined the second and third steps. Since the thimble is at zero, we know it is exactly on a mark; therefore, we could have counted four marks to the right of the number 2, which in this case is the third numbered mark, or 0.300 inch.

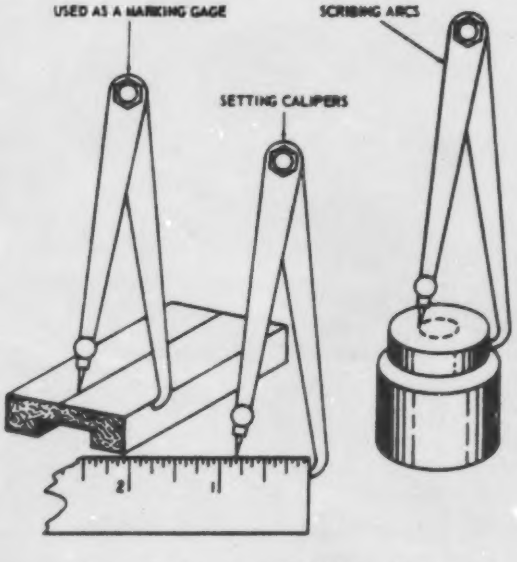

Figure 31. Using hermaphrodite calipers.

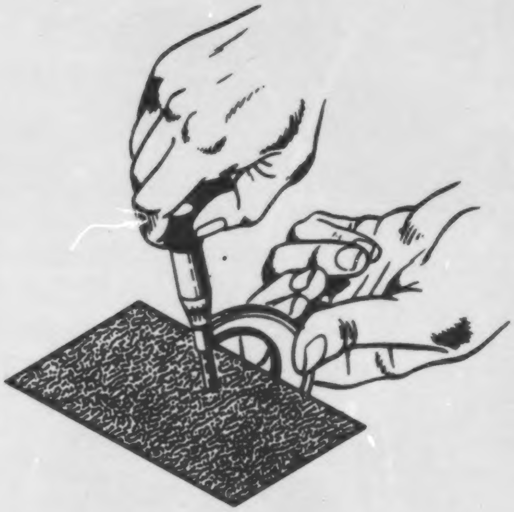

Figure 32. Measuring a flat piece of metal with an outside micrometer.

11-28. Figure 35 shows another closeup of a micrometer in four different settings. Examine each view and determine what the readings are, keeping in mind that each numbered division on the barrel represents 0.100 inch, that the numbered divisions contain four subdivisions of 0.025 inch each, and that each mark on the beveled edge of the thimble represents 0.001 inch.

11-29. *Using a micrometer.* The micrometer is a precision tool and must be handled carefully. If it is dropped, its accuracy may be permanently affected. Continually sliding work between the anvil and spindle may wear the surfaces, and if

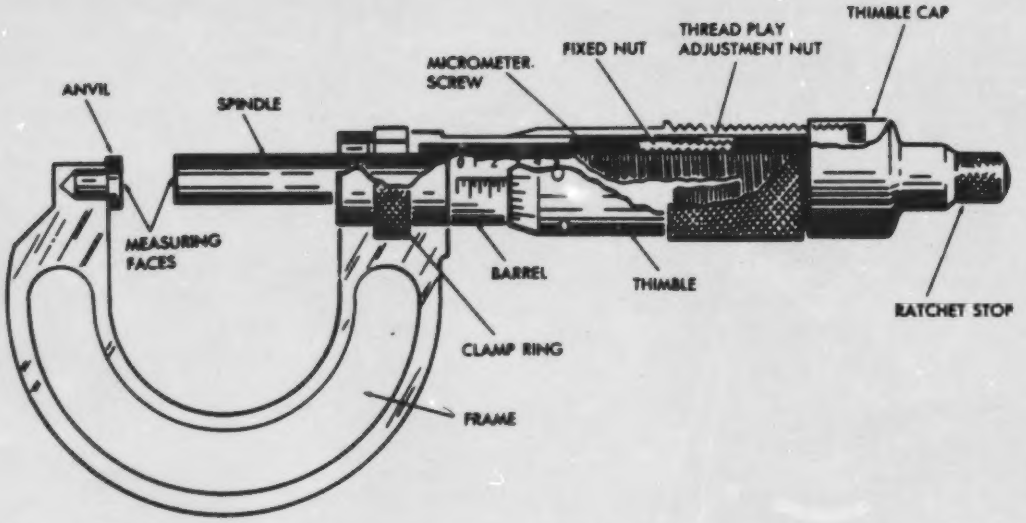
THIMBLE CAP
THREAD PLAY ADJUSTMENT NUT
FIXED NUT
MICROMETER SCREW
ANVIL
SPINDLE
MEASURING FACES
BARREL
THIMBLE
RATCHET STOP
CLAMP RING
FRAME
001-1007

Figure 33. Cutaway showing the parts of a micrometer.

the spindle is tightened too much, the frame may be sprung permanently. To measure a piece of work with the micrometer, place the work between the anvil and the spindle, as shown in figure 32, and turn the thimble until its movement has brought the spindle into contact. Remember, do not screw the thimble too tightly, since this spreads the frame and will result in incorrect readings. The measurement is read from the graduations on the barrel and the thimble, as you have already learned. After the measurement has been determined, retract the spindle by turning the thimble a few turns before removing the micrometer from the work. This practice prevents wear on the ends of the spindle and anvil.

11-30. *Vernier micrometer*. The vernier micrometer shown in figure 36 is similar to a plain micrometer except that it has an additional scale called the vernier scale. Micrometers equipped with a vernier scale make it possible to read directly the fraction of a division that may be indicated on the thimble scale. The barrel and thimble of micrometers are round, and therefore the three scales are not fully visible without turning the micrometer; however, the examples shown in figures 36 and 37 are drawn as though the barrel and thimble were laid out flat so that all three scales can be seen at the same time. The barrel scale is the lower horizontal scale, the thimble scale is vertical on the right, and the long horizontal lines make up the vernier scale.

11-31. A micrometer with a vernier scale is read in the same manner as a plain micrometer

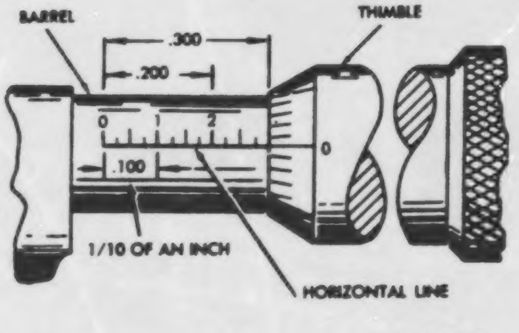
BARREL
THIMBLE
.300
.200
0
1
2
0
.100
1/10 OF AN INCH
HORIZONTAL LINE
001-1008

Figure 34. Closeup of micrometer barrel and thimble markings.

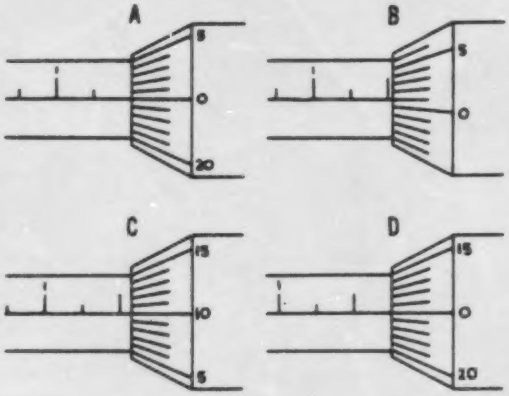
A
5
0
20
B
5
0
C
15
10
5
D
15
0
20
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Figure 35. Four representative micrometer readings.

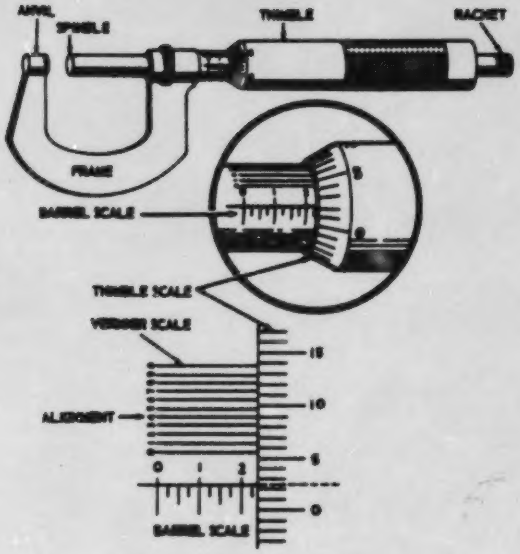

Figure 36. Vernier micrometer.

except that another step is necessary to add a fourth digit to the right of the decimal point. An excellent way to remember scale values is that the barrel scale graduations are 0.025 inch with every fourth mark numbered. Next, the thimble scale graduations are numbered every fifth mark and each 0.025 inch divided into 25 parts of 0.001 inch. The vernier scale divides each of the 25 thimble spaces into 10 subdivisions of 0.0001 inch. Remembering these scale values, you first note the barrel scale reading; next the thimble scale reading is added; then the vernier scale reading is added to get the final, or total, figure. The vernier scale line to be read is always the one aligned exactly with any thimble graduation. In figure 36, the number 4 line of the vernier scale is aligned with the number 9 line of the thimble scale.

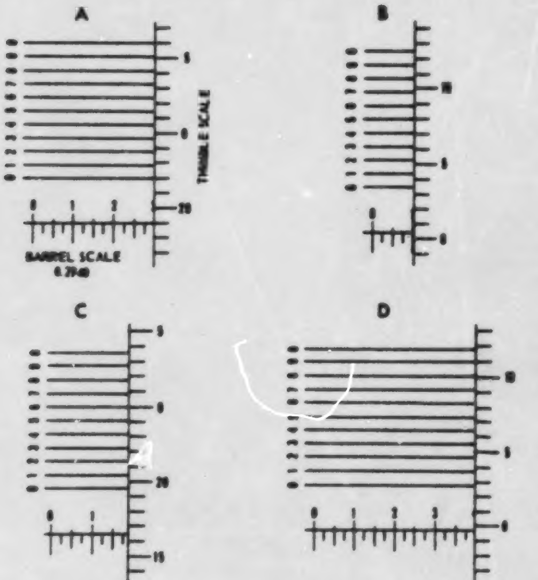

Figure 37. Four vernier scale readings.

11-32. Now practice reading a vernier micrometer by first reading the values indicated in figure 36. Beginning with the barrel scale, you can see that its reading is 0.225. To this add the 0.002 from the thimble scale, and finally add the 0.0004 from the vernier scale. The sum of these three readings is 0.2274 inch. Next turn to figure 37. In detail A the barrel reading is 0.275 plus the thimble reading of 0.019 plus the vernier reading of 0.0000, making a total of 0.2940 inch. Three other readings are shown in details B, C, and D; see if you can figure out the values shown.

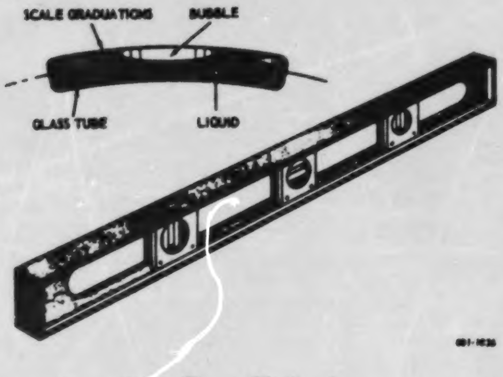

Figure 38. Level.

12. Layout Tools

12-1. In the preceding section, you studied the measuring tools used in sheet metalwork; now let's consider related items called layout tools. Some layout tools are used for both measuring and layout operations. One example is the framing square which is used for laying out right angles as well as for measuring. In the following paragraphs, we will discuss layout tools primarily used outside the shop, such as the level and plumb line, as well as layout tools used primarily in the shop, such as the T-square, triangles, dividers, pencil compass, and architect's scale. Let's begin with the level, since you have already learned that it is used with a framing square to determine the pitch of a roof.

12-2. **Level.** The level shown in figure 38 is typical of most levels, although others may be longer or shorter or may be made of wood. All levels have one or more glass vials which are

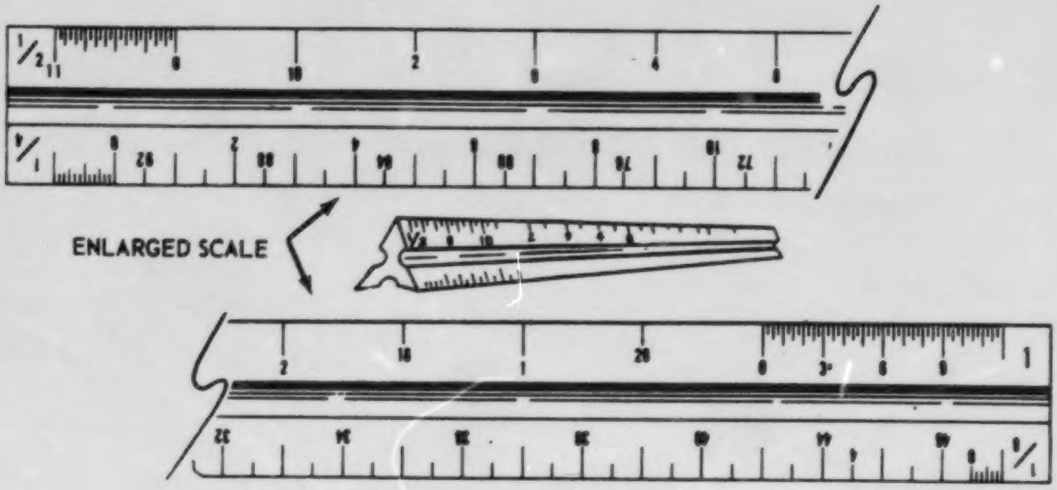

Figure 39. Architect's scale.

tubular in shape and bent in a slight arc. The vial with closed ends contains fluid (usually alcohol) and a bubble of air, and when held horizontally the bubble will move to the highest point of the arc. The glass is etched (marked) at this highest point, as shown in the illustration. The vial is then accurately installed in a frame so that when the frame is level the bubble will center itself between the two etched marks.

12-3. The level illustrated in figure 38 has six vials—two for horizontal leveling and four for vertical plumb. (Level means parallel with the horizon, and plumb means perpendicular to the horizon.) The enlarged detail in the illustration shows how the vials are mounted in pairs so that leveling can be made with either side or either end of the level.

12-4. In sheet metalwork, you will frequently use the level for determining the level or plumb condition of components being installed or for checking the condition of components already installed. For example, you may be checking a duct to see if it is level, or you may have to make a level installation of a duct.

12-5. **Architect's Scale.** If an object is too large to be drawn full size, it can be drawn in reduced proportion. This is frequently done on blueprints and working drawings of the sheet metal components which you will be fabricating and installing. In normal measuring practices, 1 inch on a rule or tape represents 1 actual inch; however, a large article such as a 10-foot section of gutter cannot be drawn full scale on a normal size sheet of drawing paper. Therefore, we use scale measurements of reduced proportions. One example of a reduced scale is to use a standard rule or tape and let each inch represent 1 foot. This is commonly called a 1″ = 1′ scale.

12-6. To make scale measuring and drawing easier, we use the triangle-shaped architect's scale, shown in the enlarged figure 39, which has several different scales for measuring or drawing reduced proportions. In using the figure, remember that only the two ends of the scale are shown. The center section is missing. At the right end of the scale, you can see the number 1, which is the 1″ = 1′ scale. Reading from the zero mark to the left you see 1, 211. Each mark represents 1 foot. Thus, the 1″ = 1′ scale can be used to make a scale drawing such as the 10-foot section of gutter. Using the 1″ = 1′ scale, you can represent the length of the gutter by the distance from the zero mark to the number 10. Here we are measuring in inches but thinking of the number 10 as feet (actual full size).

12-7. By now you are probably wondering, "Why begin measurements at the zero mark on the scale?" and "What are the small graduations next to the zero mark?" Well, these small graduations (reduced scale) represent fractional parts of a foot or inches per foot. Notice that the zero mark is placed so that feet can be measured in one direction and inches in the other. Thus, when reading to the left of the zero mark on the 1″ =

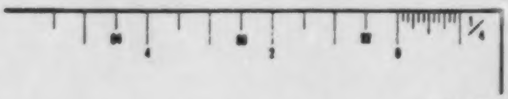

Figure 40. Architect's quarter scale.

1′ scale, think of feet; when reading to the right, think of inches. You can measure up to 12 inches on the reduced scale. *Example:* When you use the 1″ = 1′ scale illustrated in figure 39, a line drawn from the 10 mark to the left of zero to the 3 mark at the right of zero will represent an actual line 10 feet 3 inches long.

12-8. Now look at the left end of the architect's scale shown in figure 39. This is the 6″ = 1′ scale, which is commonly called the "half-size" scale. Numbers on this scale also represent feet and inches. The reduced scale to the left of the zero mark represents 12 inches divided into fractional parts, and the numbers to the right of zero represent feet. *Example:* When you use the 6″ = 1′ scale, a line drawn from the number 20 (right side of zero) to the midpoint of the reduced scale (left of zero) will represent a distance of 20 feet 6 inches.

12-9. Figure 40 shows an enlarged portion of the quarter scale (¼″ = 1′). Notice that the inch scale to the right of the zero mark is marked off in 12 increments, each representing 1 inch. *Example:* The quarter scale can be used to reduce a distance of 4¼ feet by drawing a line from the 4-foot mark on the scale to the 4-inch mark.

12-10. Other scales on the architect's scale include 3/32″ = 1′, ⅛″ = 1′, 3/16″ = 1′, ¼″ = 1′, ⅜″ = 1′, ¾″ = 1′, 1½″ = 1′, and 3″ = 1′. When measuring with an architect's scale, remember to think full size and read the larger graduations from zero as feet and the small increments on the other size of zero as inches.

12-11. **Pencil Compass and Dividers.** The two dividers shown in figure 41 are the wing type and the spring type. Each consists of two pointed branches or legs, joined at the top by a pivot. The two straight legs are tapered to a needle point. Dividers are used to transfer dimensions from working drawings to metal surfaces, to scribe circles and arcs, and to perform graphic solutions to problems such as are discussed later in this section.

12-12. The pencil compass is similar to dividers but is used most often on paper or on metal where damage to surfaces is likely to occur. The pencil compass shown in figure 42 has two legs joined at the top by a hinge and a knurled handle. One leg is tapered to a needle point; the other has a pencil lead inserted. The compass is used to scribe circles and arcs, to perform graphic solutions to problems, and to transfer measurements from the steel rule to the job. However, more accuracy is obtained in transfers of measurements with dividers than with a compass.

12-13. To draw an arc or circle with either dividers or a compass, hold the thumb attachment on the top with the thumb and forefinger. With pressure exerted on both legs, swing in a clockwise direction and draw the desired arc or circle, as shown in figure 42. The tendency to slip is avoided by inclining the compass or dividers in the direction in which they are being rotated. On aluminum or stainless steel, the divider is used only to scribe arcs or circles that will later be removed by cutting; all other arcs or circles should be drawn with a pencil compass to avoid scratching the material.

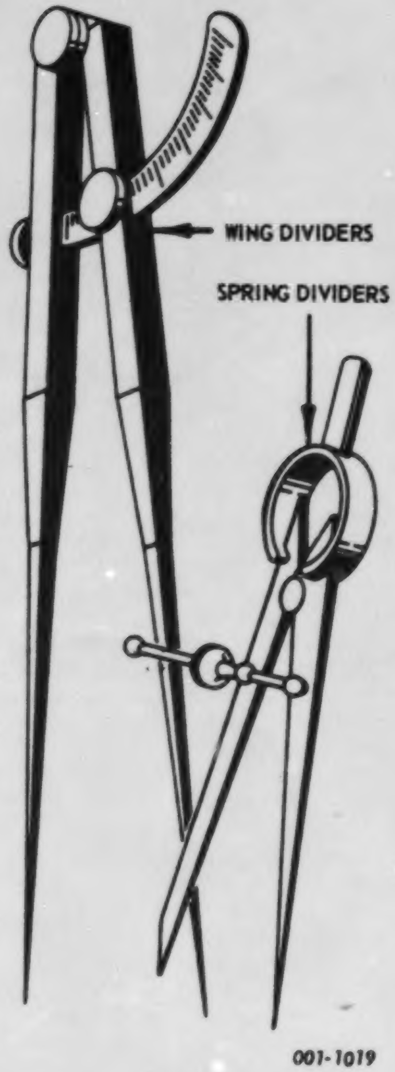

Figure 41. Dividers.

12-14. *Transferring measurements with compass and dividers.* The following procedure is suggested for using dividers and compasses to transfer measurements from a steel rule. To set either one, hold it in one hand, place the point of one leg in the graduations on the steel rule as shown in figure 43, and adjust the other leg until the point rests on the desired graduation of the steel rule. This spread represents the required measurements which may be transferred to patterns or metal. In the following paragraphs, you will learn how the compass and dividers are used to perform graphic solutions which will be useful in laying out patterns for sheet metal objects.

12-15. *Graphic solutions with compass and dividers.* In addition to scribing arcs and transferring measurements, compasses and dividers can be used for such operations as stepping off the circumference of a circle into equal parts as you did when constructing the polygons in Chapter 2 of this text. But now let's think about other ways these handy layout tools can be used, such as in graphic solutions which do not require arithmetic figuring. In sheet metalwork, you will frequently need to lay out circles, diameters, radii, perpendicular lines, various polygons, etc.

12-16. In figure 44, you can see how a line can be bisected (divided into two equal parts). Of course, the line could be measured with a rule and mathematically divided into two parts, but it can also be bisected with compass or dividers. To divide line AB into two equal parts, use the compass to form a radius greater than one-half of line AB, and draw two arcs with A and B as the centers. Then draw a straight line through the two intersections of the arcs to divide line AB into two equal parts. This line is also perpendicular to line AB.

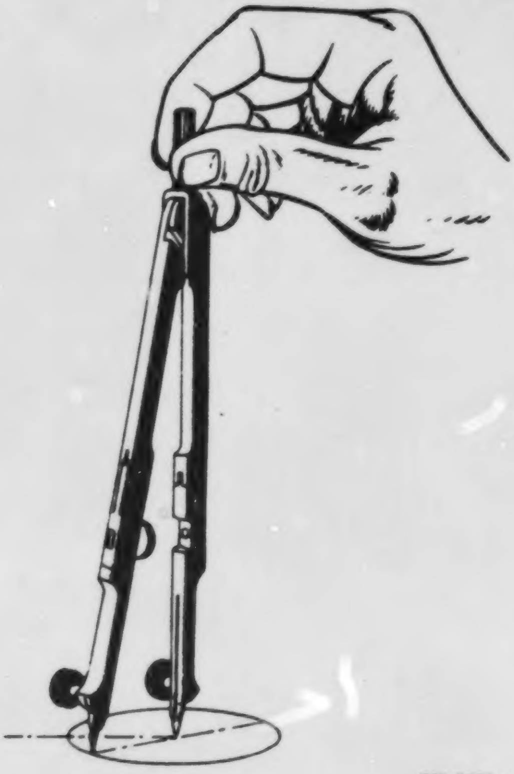

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Figure 42. Pencil compass.

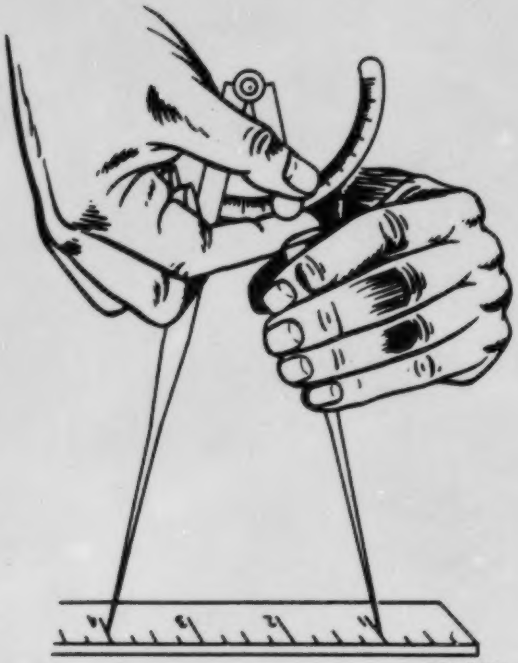

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Figure 43. Transferring measurements with dividers.

12-17. In figure 45, you can see how a perpendicular can be drawn from a given point on a line. With point C as a center, draw two arcs crossing the horizontal line at A and B; then draw two arcs with points A and B as centers. The line drawn from C to D will be perpendicular to the horizontal line at point C.

12-18. Figure 46 shows how to draw a line parallel to a given line. First draw two perpendiculars from points A and B; then with points A and B as centers and any given radius (the distance between the parallel lines) draw two arcs CD and EF. A line drawn from points G through H will be parallel to line AB.

12-19. Figure 47 shows how any angle can be bisected. With O as a center and using any radius, draw the arc AB. Then using points A and B as centers, draw two arcs that meet at point C. Now a line drawn between points O and C will bisect the angle AOB.

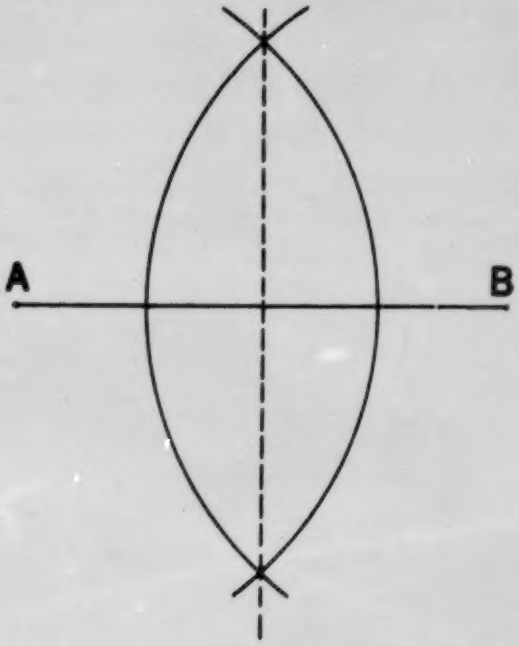

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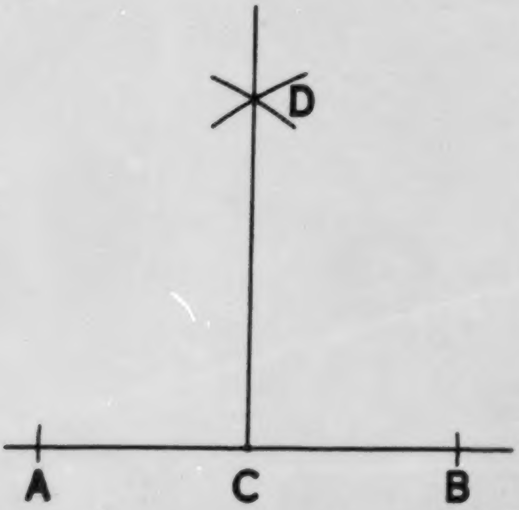
Figure 44. Bisecting a line and drawing a perpendicular.

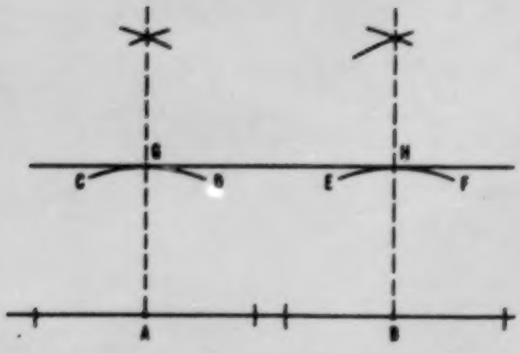
12-20. Figure 48 shows how to find the center of a circle. This is done by drawing two chords such as AB and CD, then bisecting each with perpendicular lines. The two perpendiculars will cross at the center of the circle.

12-21. Figure 49 shows how two parallel lines are connected with an ogee (S) curve. This is done by first connecting B and C with a straight line, then selecting a point such as E through which the curve is to pass. Lines BE and CE are each bisected and two arcs constructed: arc BE from center point F and arc CE from center point G. These two arcs connect the parallel lines AB and CD. In sheet metalwork, you will use ogee bands in rain gutters, the side pieces for duct offsets, and anywhere sheet metal is formed into a reverse or S curve.



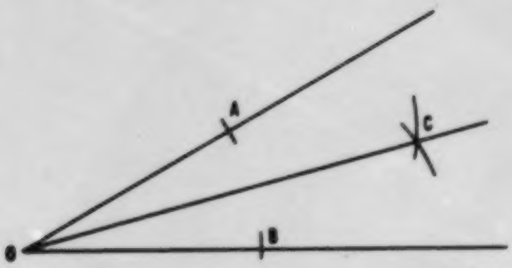
530-242

Figure 45. Drawing a perpendicular to a straight line at a given point.



530-243

Figure 46. Drawing a line parallel to a given line.



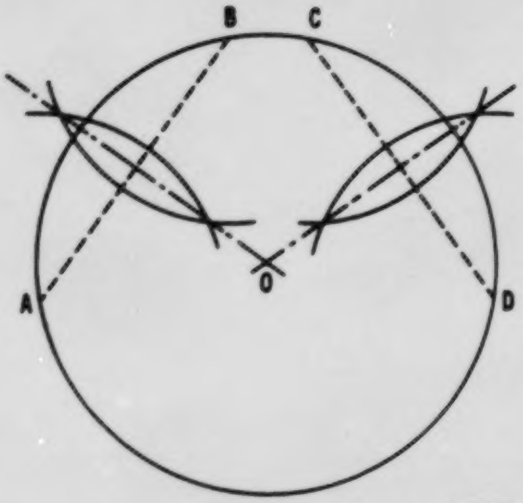
530-244

Figure 47. Bisecting an angle.

12-22. Figure 50 shows how a pentagon may be constructed inside a circle. First draw a diameter line AB with radius line OC perpendicular to it. Line OB is bisected with point D at the center. Draw arc CE from center D. Then draw arc EF from center C. The radius CF is the length of each of the five sides which may be stepped off and connected with chords.

12-23. Figure 51 shows how a hexagon may be constructed inside a circle. With points A and B as centers, draw two arcs equal to the radius. The points where these arcs cross the circle will be the corners of the hexagon when chords are drawn between AC, CD, BD, BF, EF, and AE.

12-24. Figure 52 shows how a square can be drawn inside a circle by dividing the circle into quarters with two diameters at right angles to



530-245

Figure 48. Locating the center of a circle.

each other. When points A, B, C, and D are connected with chords, a square is formed.

12-25. Figure 53 shows how an octagon can be drawn inside a circle by dividing the circle into quarters and bisecting an angle such as AOC. The length of chord AE will be the same as each of the eight sides which are stepped off with the compass. Each point is then connected with chord lines.

12-26. Many other graphic solutions are possible with the use of a compass or dividers; however, the 10 examples discussed in the preceding paragraphs will be used most often. Your knowledge of these basic uses will lead to various other combinations which may arise in laying out patterns for sheet metal objects. In Chapter 5, you will find additional use for the compass and dividers for graphic solutions in the development and layout of sheet metal patterns.

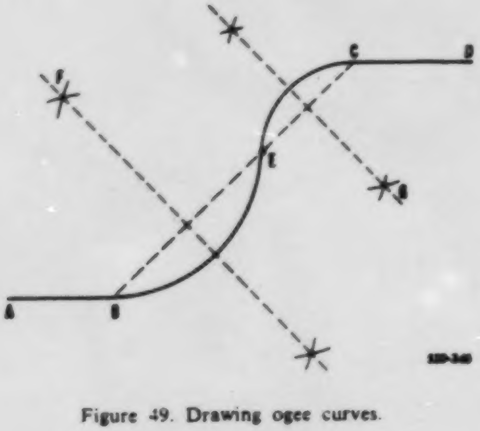


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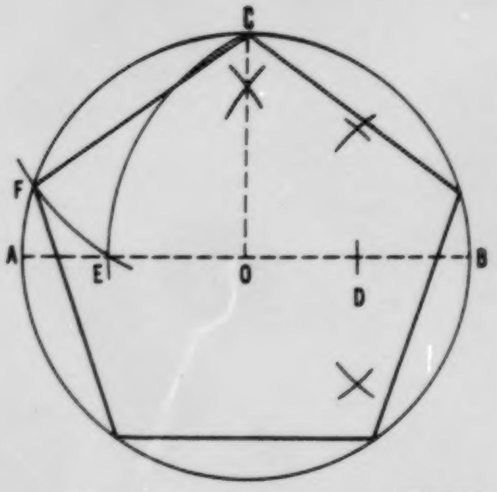
Figure 49. Drawing ogee curves.



530-247

Figure 50. Drawing a pentagon inside a circle.

12-27. **T-Square and Triangles.** Figure 54 shows two triangles and a T-square on a drawing board. The T-square shown has a head made of wood and a blade made of wood with transparent plastic edges. These edges are used as a straight edge for marking horizontal lines and as a base line for the triangles. With the T-square held firmly, it is easy to draw 30°, 45°, 60°, and 90° angles from the base line. These layout tools will be very useful when you are making patterns and layouts, since many sheet metal components are drawn with straight lines. Triangles are usually made of plastic and are available in various sizes. the 8- to 12-inch sizes are suitable for most sheet metal pattern development.

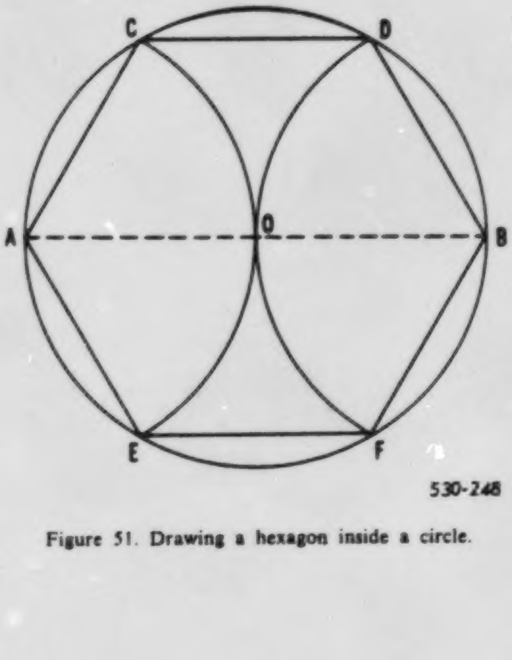


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Figure 51. Drawing a hexagon inside a circle.

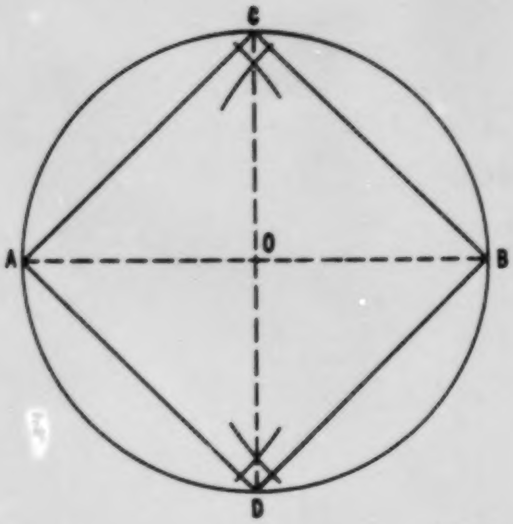

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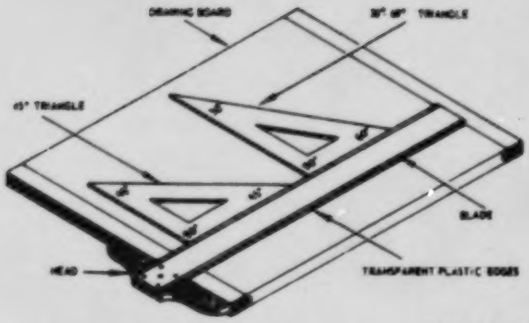
Figure 52. Drawing a square inside a circle.

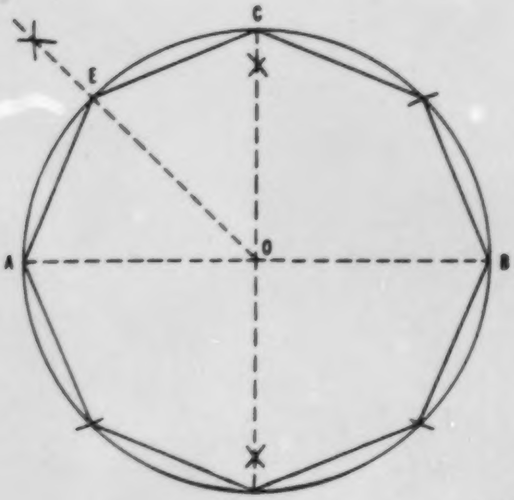


530-104A

Figure 54. T-square and triangles.

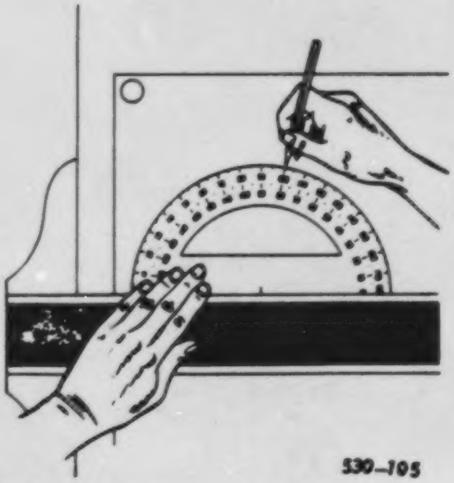
12-28. **Protractor.** It is sometimes necessary to measure or draw angles other than the common 30°, 45°, 60°, or 90° variety. When this need arises, a protractor like the one shown in figure 55 can be used. The protractor is a semicircular scale divided into 180 equal parts (180°). it is usually made of plastic, and it is used for drawing and measuring angles. Its function is similar to that of the turret protractor head of the combination set which you studied earlier in this chapter, except that a protractor lies flat and is used on the drawing board or pattern layout table with a T-square. Notice in the illustration that the protractor has two scales; and at a point near the pencil you can see a calibration where 100° and 80° are at the same location. If you examine all such numbered calibrations, you will find that the two at each location can be added together for a sum of 180°. The two scales are the equivalent of a left and a right protractor combined. To measure or draw an angle with a protractor, the index point which is located on the base line (near the left-hand index finger in the illustration) is used at the vertex of the angle. For example, if the base line of the protractor is placed on a straight line and another line is drawn from the index point to the 100° and 80° point, the smaller angle on the right will be 80°, and the larger angle on the left will be 100°.

12-29. **Templates.** Patterns that are used repeatedly are made of metal and are called templates or master patterns. If paper patterns are used repeatedly, they soon become worn and inaccurate. When several identical items are to be made, you will save time by preparing a tem-



530-250

Figure 53. Drawing an octagon inside a circle.



530-105

Figure 55. Protractor.

plate. Figure 56 shows a metal template of a cylindrical pipe cut at an angle, and a scriber is being used to mark the lines to be cut. Templates larger than the one illustrated are usually held in place with clamps while the scriber is used.

12-30. **Irregular Curves.** Irregular curves are plastic devices sometimes called *French curves* which are used to draw lines with irregular curvature. The devices are available in various shapes and sizes, but all are used in a similar manner. In figure 57, the irregular curve is being used to connect points on the grid. Notice that the curvature needed to connect the last two points will not be the same as the curvature which connected the other points. The template shown in figure 56 was made from a pattern that involved connecting points not in a straight line.

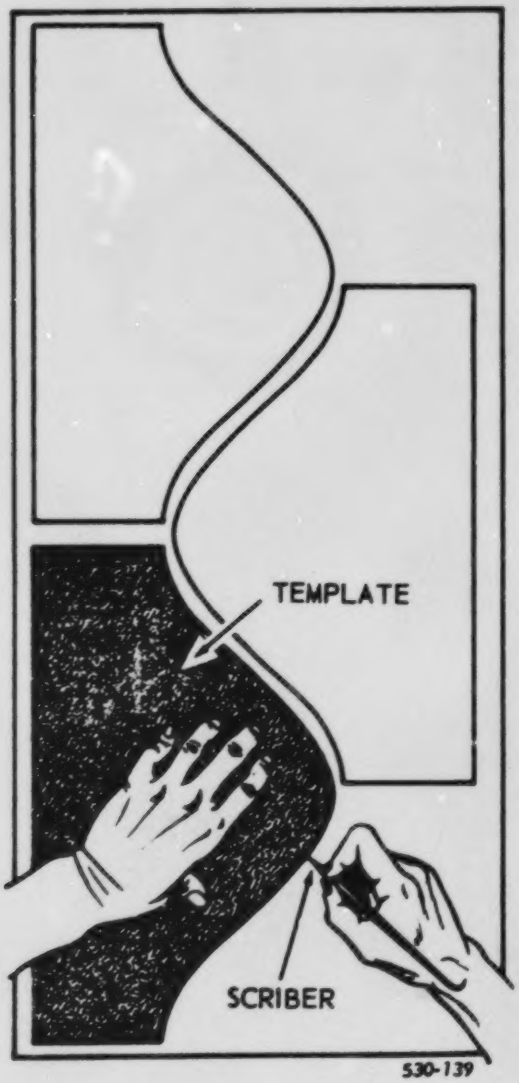


Figure 56. Using a template.

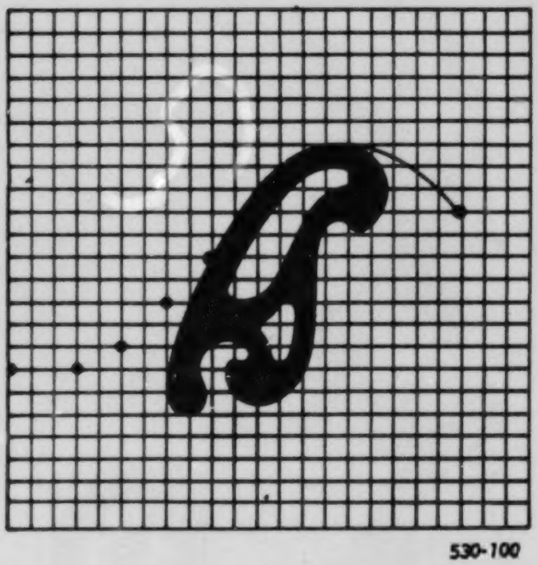


Figure 57. Using an irregular or french curve.

12-31. **Trammel Points.** Sometimes ordinary dividers are not large enough for a particular application. In this case, you use a set of trammel points such as the one shown in figure 58. Trammel points are sometimes called beam compasses and are used to lay out large circles and arcs or to transfer dimensions from one location to another. The trammel points shown in figure 58 are typical, although others may have different shaped adjustment screws and a round, flat, square, or triangular shaped bar which may or may not be calibrated in feet and inches. The information you have just learned concerning transferring measurements and graphic solutions with compasses and dividers will also apply to the use of trammel points.

12-32. **Plumb Line.** A plumb line like that shown in figure 59 consists of a weight hung at the end of a line to determine whether a wall downspout, etc., is vertical. The word "plumb" also means vertical; therefore, a plumb line is a

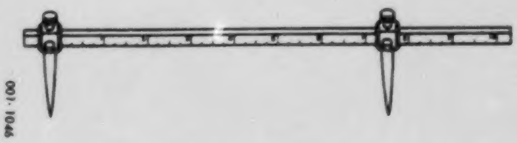


Figure 58. Trammel points.

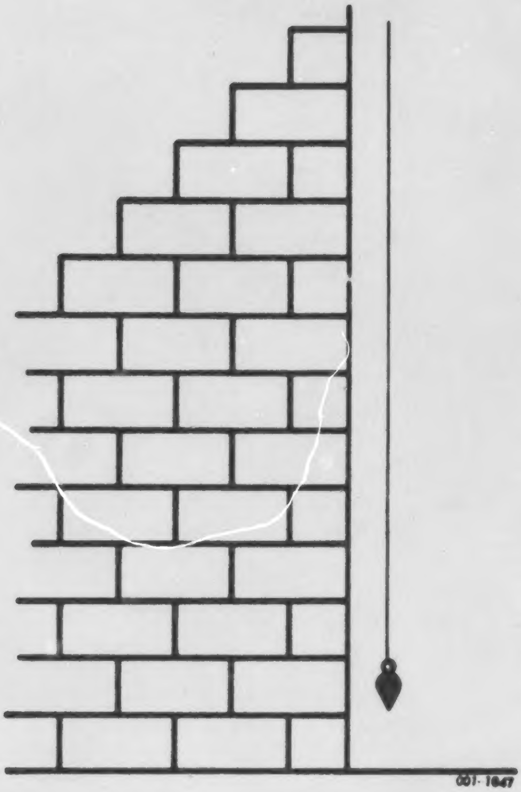


Figure 59. Plumb line.

vertical line. One of the uses you will find for plumb lines is to establish a vertical reference line when installing rain gutter downspouts on the sides of the buildings. Plumb lines are normally used when installing long vertical objects, and a carpenter's level is used for determining vertical plumb of shorter objects. The pointed weight of a plumb line is called the plumb bob and is usually made of brass or coated steel. Plumb bobs have various means for attaching to the line; however, the bob illustrated in figure 59 simply has a hole through which the line is passed and tied. When an object is not vertical, it may be called *out of plumb* or *off plumb*.

12-33. **Chalk Line.** A chalk line as used in the building trades is a length of heavy cotton cord stretched between two points to provide a straight reference line for installation of such items as roofing, siding, gutters, ducts, etc. Chalk lines are sometimes yellow in color and are available in various lengths. Colored chalk is rubbed on the line so that it will leave a straight line of powdered chalk when stretched between the two points and snapped lightly. A chalk line can be used as a reference line that is level, vertical, or with a *drop*, such as for a gutter that is designed to make water drain toward a downspout.

CHAPTER 4

Working Drawings

WORKING drawings, sometimes called plans or blueprints, are used by workmen in all crafts and trades—such as carpenters, electricians, and sheet metal specialists. The lines and symbols used on working drawings may be compared with the lines and symbols used on roadmaps, where different kinds of lines indicate types of roads and where symbols identify the roads as Federal, state, or county. Other symbols identify state capitols, county seats, airports, ferries, etc. Maps also show the distances between towns and cities and their size.

2. The working drawings which you will be using can be compared with roadmaps too, since they also contain solid and dashed lines that outline objects and show routings, symbols which abbreviate and identify components, and dimensions which show the distances between components and how large they are.

3. The symbols and instructions contained on working drawings must be carefully followed if a component is to be properly fabricated and installed. For example, suppose you have made the duct work for a heating system but another person has failed to adhere to specified dimensions for the opening in the wall through which the ducts must run. Because of his failure to follow instructions in the working drawings, the ducts cannot be installed without additional expense and delay. Remember, then, that careful adherence to the plans is very important.

4. In this chapter, we will discuss the use and interpretation of lines, symbols, dimensions, specifications, and notes used in working drawings. These subjects are in accordance with your specialty training standard, which states that the sheet metal specialist uses and interprets drawings, diagrams, charts, and tables in relation to assigned tasks. The knowledge you gain from this chapter can be used every time you develop patterns, fabricate components, or install components.

13. Types of Drawings and Views

13-1. Drawings that you use will convey ideas concerning the fabrication, assembly, and installation of sheet metal components. From a working drawing, you can learn what the architect or engineer intends for you to build. The drawings will be duplicates made by photographic reproduction processes such as blueprints or ammonia developed ozalid prints. These prints will be approximately 30" x 40" in size. In the following paragraphs, we will explain some of the types of views and drawings the draftsman uses to graphically describe the jobs you are to perform.

13-2. **Pictorial and Orthographic Projection Drawings.** In figure 60, you can see the relation of pictorial and orthographic projection drawings. View A is a pictorial drawing, so called because it is similar to a picture. In view B, you can see how the pictorial has been redrawn but without shading lines (both views are pictorial). The other three unshaded views in B are called orthographic projections and show the true size of each side of the rectangular prism. Two or more views of orthographic projections are usually at right angles to each other and perpendicular to the plane of projection. Notice how the unshaded top, front, and ends shown in B have been projected so that each resembles a rectangular plane. In the pictorial view, it appears that the angles at the four corners are not equal, whereas in the projection views we can see that all of the angles are equal. Pictorial drawings always show the features of an object in a somewhat distorted way and are used only to a limited extent in working drawings. Orthographic projection drawings, on the other hand, have the advantage of showing all the features in their true shape.

13-3. In orthographic projection drawings, such as that illustrated in figure 60, three views of the object are shown. This is done to show you the three main dimensions—length, width,

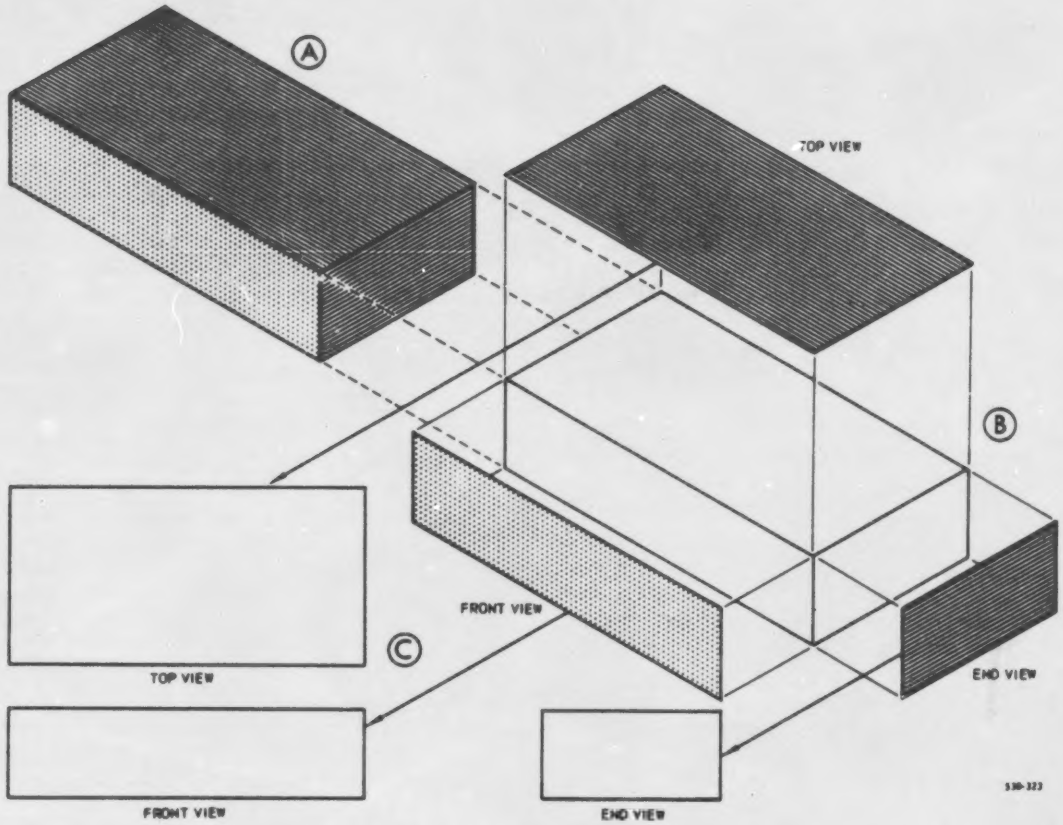


Figure 60. Pictoral and orthographic protection drawings.

and thickness. The orthographic projection showing the top is called the top or plan view. It shows that part which would be seen if you were standing directly over the object and looking down at it. The orthographic projection showing the front is called the front or elevation view. It shows that part of the object which would be seen if you were standing directly in front of the object and looking squarely at it. The orthographic projection of the end is used to show the distance from the front to the back. It is also an elevation view and shows the part of the object which would be seen if you were standing at the end and looking squarely at the object. As you can see in simple orthographic projections of regular shapes like this, the end view is not important because all dimensions are obtainable from the top and front views.

13-4. Curved surfaces do not always look curved in an orthographic projection because you are looking at the top, bottom, or side of an object 90° to the surface. In a pictorial drawing, you can see that the edges are curved; but in an orthographic projection, you see the surface broadside, and it appears flat. The example shown in figure 61 is a two-view orthographic drawing of a cone. Although you know that the side of a cone is curved, you cannot see the curvature in the drawing. However, from the accompanying plan view, you can see that the base of the elevation view is circular. It is a good idea to keep in mind that the curves in orthographic projections do not show curved surfaces but may indicate a curved surface, and it is up to you to determine the curvature from one of the other views.

13-5. **Types of Views.** Working drawings will provide you with sufficient information to develop patterns and fabricate, assemble, and install the components represented. This includes such information as size and shape of the components and how installed. Working drawings are usually divided into three general classes—detail drawings, assembly drawings, and installation drawings; however, in sheet metal drawings these classes are combined into plan views (plans), elevation views, and detail views.

13-6. *Plan views.* In this chapter, we have already mentioned plan views and have used two figures to illustrate them. In the orthographic projections shown in figures 60 and 61, the plan views show the objects as they would be seen if you were standing directly over them and looking down. This is also true of an architectural drawing, where the plan view is an overhead view of the floor plan, as shown in figure 62. In this plan view you can see how a heating system is installed.

13-7. A plan view such as that illustrated in figure 62 includes much of the information necessary for installation of components or assemblies in a building. It shows the dimensions necessary for locating the parts with relation to other parts, and it shows room dimensions which are helpful in the various layout and installation problems. Notice in the illustration such information as the overall appearance of the installed duct system, the size and shape of the duct pieces, the room dimensions, the grill locations, the direction of airflow, and the location of underfloor return ducts. Now that you have looked over the drawing of the duct system, you are probably wondering about the symbols and different kinds of lines used. Later in this chapter, we will discuss lines and symbols; however, at this point it is more important that you learn about plan, elevation, and detail views.

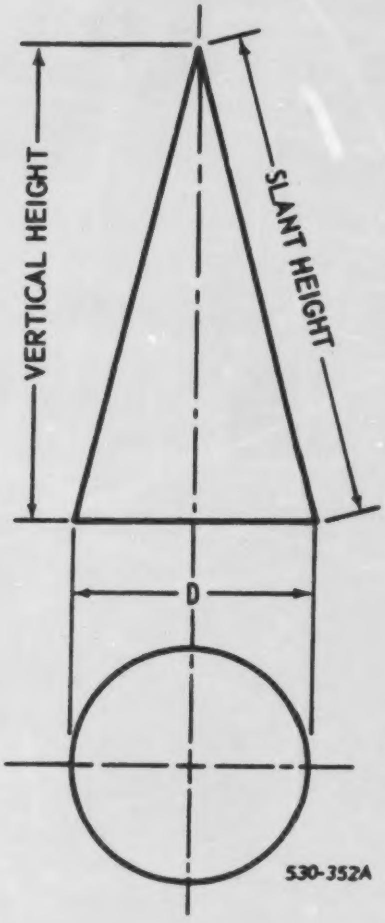


Figure 61. Orthographic projection of a cone.

13-8. *Elevation views.* In figures 60 and 61, two simple elevation views are illustrated. Now, in figure 63 you can see the elevation view of a furnace and supply trunk. Notice that this side view contains information that cannot be shown in a plan view. From elevation views of this type, you can also determine vertical dimensions and distances which are needed for pattern layout, fabrication, and installation. In sheet metalwork, elevation views similar to this are often contained on the same working drawing as the plan views.

13-9. *Detail views.* Detail views often show small parts that cannot be clearly seen in the plan and elevation views. For example, the detail view shown in figure 64 illustrates the use of a cloth connector and methods of making the connection. This cloth connector is used to prevent furnace noise from being transmitted through the duct system. You will find detail views similar to these included with most plan and elevation drawings which include descriptions such as size, specifications, shape, materials, and methods of fabrication.

14. Descriptive Terms and Dimensions

14-1. In this section, we will discuss dimensioning terms, use of lines, dimensions, and scale measurements that are applicable to working drawings of sheet metal components.

14-2. **Dimensioning Terms.** In Chapters 2 and 3 of this text, we reviewed how to measure with graduated scales using whole numbers, fractions, and decimals. Now let's see how measurements, or dimensions as we will call them, are used on working drawings. To accurately understand the dimensions of an object, it is necessary that you and the draftsman follow the same definition of terms such as length, width, height, etc.

14-3. *Length.* This term usually refers to the greatest dimension of an object or the greatest dimension of any part of the object being described. For example, figure 65 shows a board to which a cleat has been attached. We speak of the board as being 24 inches in length and, at the same time, of the cleat as being 18 inches in length. In both cases, the length is the greatest dimension of the object.

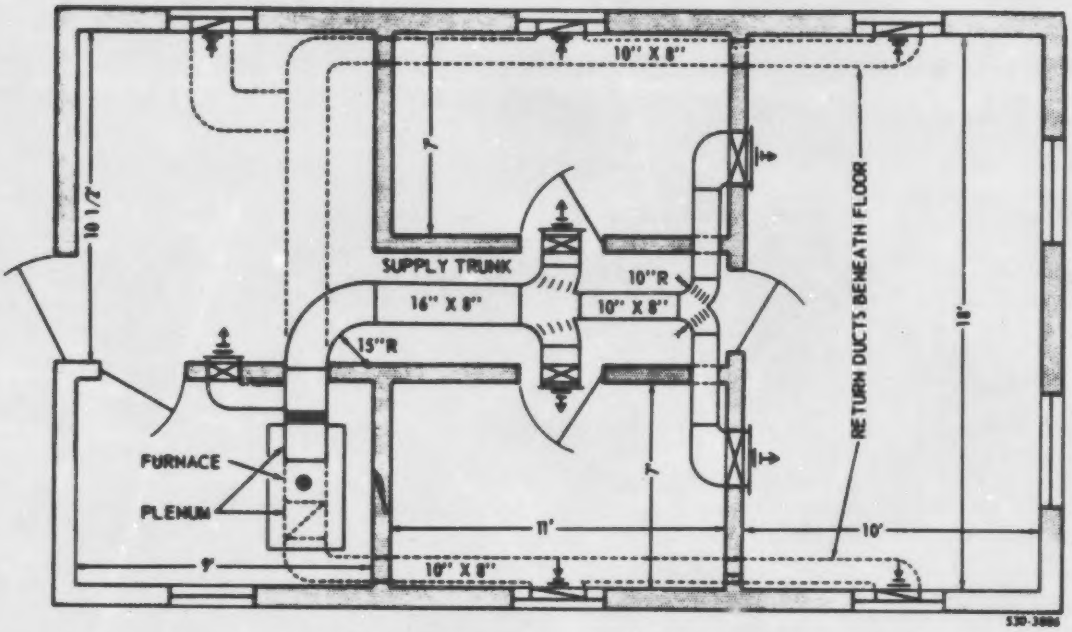

10" X 8"
7'
10 1/2'
SUPPLY TRUNK
16" X 8"
10"R
10" X 8"
15"R
FURNACE
PLENUM
RETURN DUCTS BENEATH FLOOR
18'
7'
11'
10'
9'
10" X 8"
530-3886

Figure 62. Plan view of a duct installation.

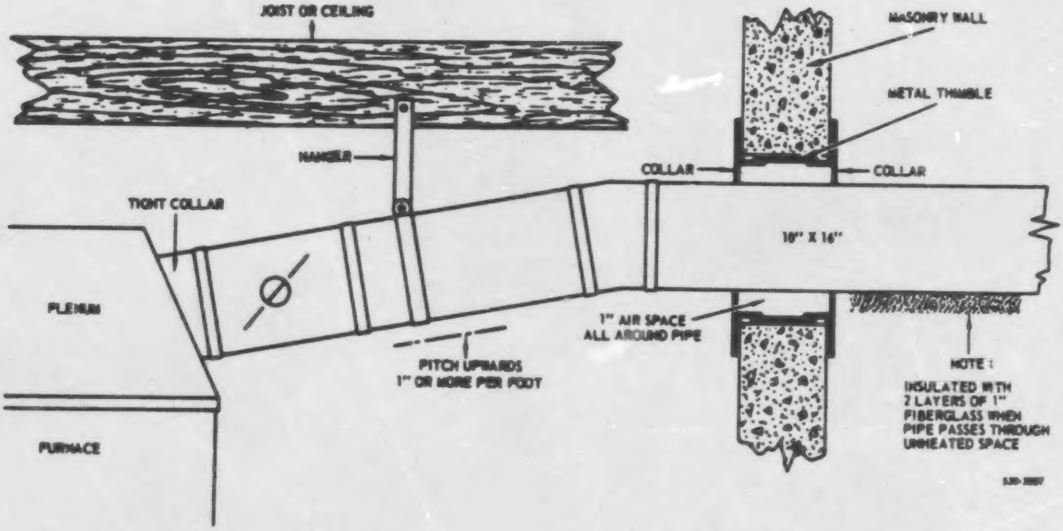

JOIST OR CEILING
MASONRY WALL
METAL THIMBLE
HANGER
COLLAR
COLLAR
TIGHT COLLAR
10" X 16"
PLENUM
1" AIR SPACE ALL AROUND PIPE
PITCH UPWARDS 1" OR MORE PER FOOT
NOTE: INSULATED WITH 2 LAYERS OF 1" FIBERGLASS WHEN PIPE PASSES THROUGH UNHEATED SPACE
FURNACE
530-3887

Figure 63. Elevation view.

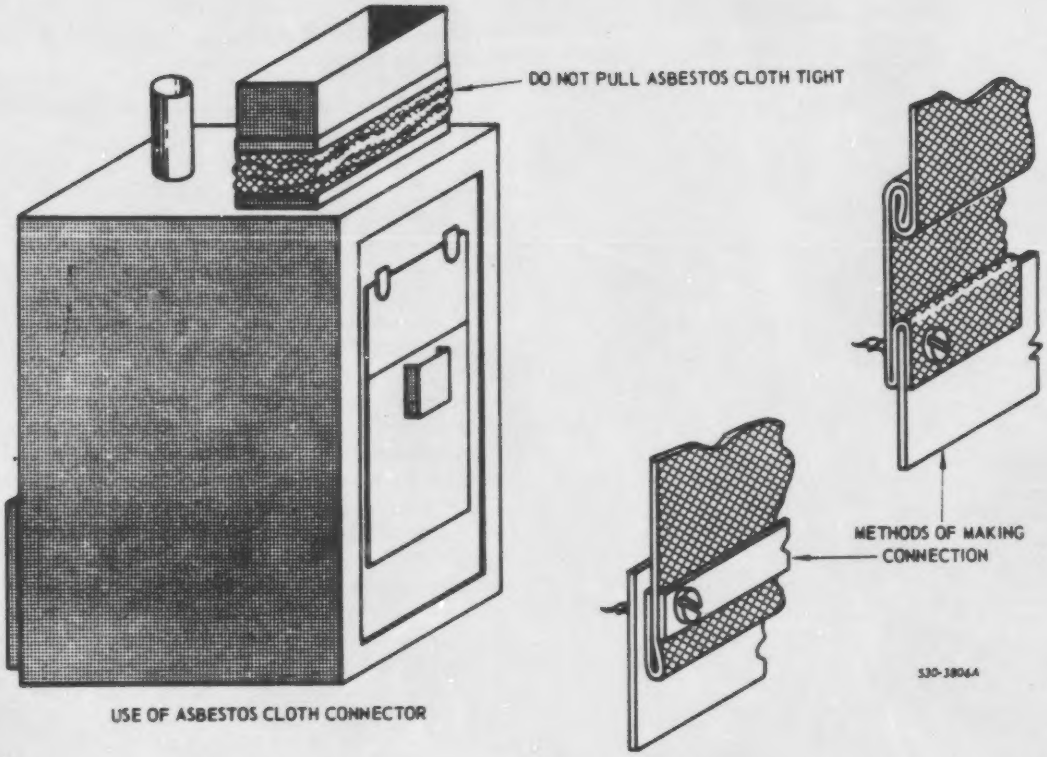

DO NOT PULL ASBESTOS CLOTH TIGHT
METHODS OF MAKING CONNECTION
530-3806A
USE OF ASBESTOS CLOTH CONNECTOR

Figure 64. Detail view of a duct connector.

14-4. *Width.* The term "width" usually refers to the dimension of an object from side to side or in a direction at right angles to the length. In figure 65, the board is 18 inches in width and the cleat is 3 inches in width.

14-5. *Thickness.* This term usually refers to the smallest dimension of any part of the object being described. Thickness can apply either to the main part of the object or to some separate part attached to the object being described. It can also apply to a part projecting from the object; however, it does not apply to a groove that is cut in an object. Figure 65 shows us that the board is ¾ inch in thickness and that the cleat is also ¾ inch in thickness.

14-6. *Height.* This term is used to indicate a dimension of an object, or a part of it, which rises above either the surface of the object being described or the one upon which it stands. For example, if you place a block upon a table in a position so that its greatest dimension is upright (standing on end), you would refer to the dimension as height instead of length. In figure 65, the center block is 3 inches high.

14-7. *Depth.* Depth is a perpendicular measurement downward from the top surface or backward from the front. Note in figure 65 the drawing of a block with a groove in the top surface. We would say this groove is ½ inch below the top surface of the block.

14-8. **Lines and Their Use.** Your ability to read this printed page depends upon your skill in recognizing the letters of the alphabet. In addition to recognizing these letters, you must know how they are used in the construction of words and sentences. Likewise, being able to read working drawings depends upon your ability to recognize the character of the lines used and to understand how they fit into the description of objects as represented.

14-9. *Visible outlines.* In describing an object with a drawing, the outline of all faces is represented by lines. The surfaces visible to the eye are always outlined in solid lines. Being bold, solid lines, they become the basis for comparison of the weights of all other lines. Notice the weight of these lines in figure 66.

14-10. *Hidden lines.* Surfaces which are invisible (or hidden) are outlined with dashed lines. A hidden line is actually a series of short dashes of medium weight, about half as heavy as the lines used to indicate visible surfaces. When reading working drawings, it is important for you to remember that a series of short, uniform

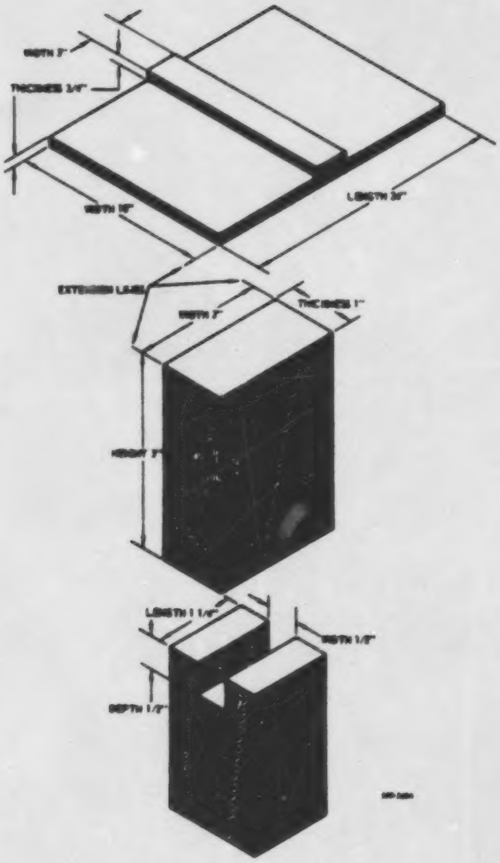


Figure 65. Dimensioning terms.

dashes always represents surfaces that are hidden. Examine figure 66 and locate the lines that indicate hidden surfaces. Also examine the invisible (dashed) lines used in figure 62. See if you understand what they represent.

14-11. *Centerlines.* For the sake of accuracy in the construction of many objects, it is essential to lay off the dimension from a centerline rather than from the edge or side. This is particularly true of circular objects or objects made up of curved parts. This centerline in a working drawing is also known as the central axis and is illustrated in figure 66, where it is used to locate holes which are to be drilled along a straight line. Note that in this case the centerline is not the center of the object but is drawn through the centers of the holes. A centerline is made up of a series of long and short dashes.

14-12. *Dimension lines.* If a working drawing is to be satisfactory, it must have not only the correct shape but also the size of the object and all of its features. The size is indicated by dimension lines which are easily recognized by the arrowheads at each end. Examine the use of dimension lines in figures 62 and 65. Notice that the dimension lines are not continuous because of a space near the center where the dimension is written.

14-13. *Extension lines.* Usually, the draftsman tries to place all dimensions of an object outside its outline. This is done primarily for neatness and clarity. In figure 65, you can see how extension lines are used so the dimension lines will be clearly understood. The solid lines extend the limits of a dimension out and away from the object and are lighter in weight than the visible outlines.

14-14. **Use of Dimensions.** Now that you have learned some of the dimensioning terms used on working drawings and how lines are used, let's consider how dimensions are used on working drawings. Although draftsmen do not always follow it, there is a standard procedure for placing dimensions on drawings. Learning this standard procedure will enable you to read working drawings quickly and accurately. Dimensions of rectangular ducts are often written on the working drawings as shown in figure 62. Notice the section of 16" x 8" duct which is 16" wide and 8" high. If this same section of duct is shown on an elevation view, it would be marked 8" x 16".

14-15. *Angles.* Dimensions of angles are shown in figure 67. Notice how the dimension lines are used and how the sizes of the angles are placed to be read from a horizontal position, regardless of the position of the angle. If the angle is too acute to be read, as shown by the 15° angle, the dimension may be placed outside the angle.

14-16. *Circles.* Figure 68 shows how dimensions are drawn for circles on working drawings. Centerlines should not be used as dimension lines; therefore, when you show diameters inside the circle, do it as shown in the upper left circle of the illustration. Notice the preferred way of showing the diameter. The two circles shown in the lower right illustrate the way holes (small circles) are dimensioned.

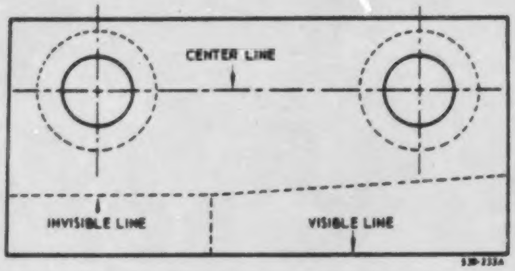


Figure 66. Visible and invisible outlines.

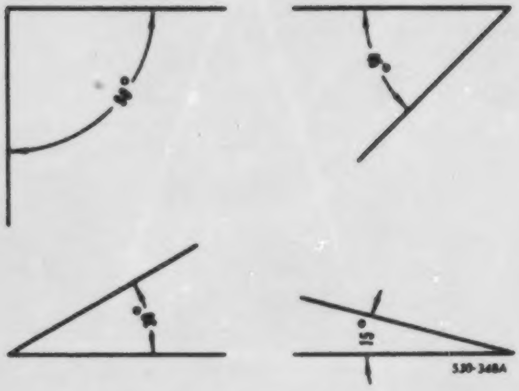


Figure 67. Dimensions of angles.

14-17. *Arcs.* Figure 69 shows how dimension lines are used to indicate the radii of arcs. Notice that an "X" is placed at the center point, with a dimension line going to the appropriate arc. In this illustration, the radius is shown for each arc, although in actual practice the drawing of a rectangular elbow like this will have only the throat radius marked. (The throat radius is the smaller of the two arcs. The radius of the larger arc is called the heel radius.)

14-18. *Holes.* For distances between holes in an object, dimensions are usually indicated from center to center rather than from outside to outside of holes. Figure 70 shows a piece of sheet metal with three equally spaced 9/16-inch diameter holes not on a centerline. Dimension and extension lines have been used to indicate various dimensions. The diameters of the three holes have been shown. The hole diameters could also have been dimensioned as shown in figure 68.

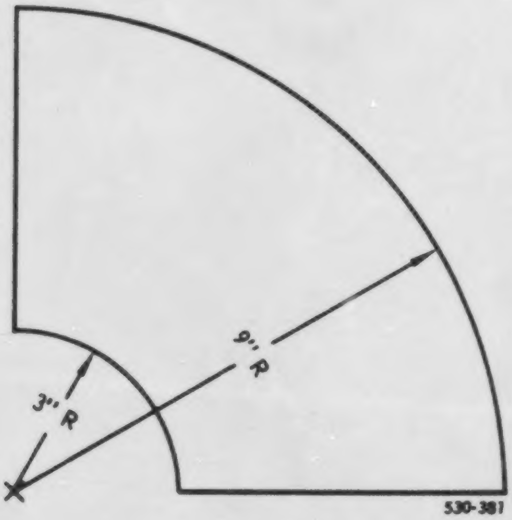


Figure 69. Dimensions of arcs.

14-19. *Geometric solids.* On working drawings the diameter for a sphere is usually given on the view which is most convenient. The two necessary dimensions for a cylinder—length and diameter—can be shown on one view. Often one view of a cone is used to indicate the diameter and height, although it is better to have two views as shown in figure 61. Two views are also desirable for working drawings showing the dimensions of a pyramid. These dimensions—vertical height, slant height, width, diameter, etc.—are shown on the working drawings in the plan, elevation, and detail views.

14-20. **Scale Dimensions.** In Chapter 3, you learned how to use the architect's scale to reduce the dimensions of objects too large to be drawn full scale. Now, let's learn how to use the architect's scale to measure objects which are drawn to scale on a working drawing. For example, a working drawing such as that shown in figure 62 will probably be drawn ¼" = 1' scale. By using the ¼" scale of an architect's scale, you can easily determine dimensions such as the length of the duct sections, distances from the wall, etc. If you have a working drawing of a very large building, the scale may possibly be ⅛" = 1' so that the entire structure can be shown on one drawing. However, in most architectural working

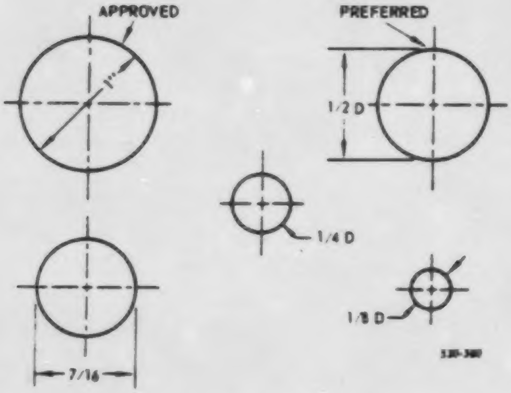


Figure 68. Dimensions of circles and holes.

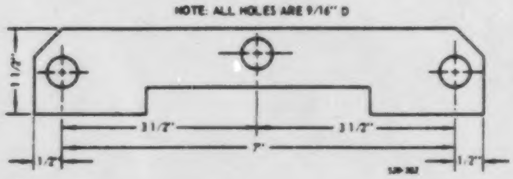


Figure 70. Dimensions for holes.

drawings you use, the scale will be ¼" = 1'. But when written dimensions are included on the working drawing, as shown in figure 62, they should be followed in preference to using the architect's scale.

14-21. If you have a working drawing of a small object such as the elbow shown in figure 69, the size will most likely be full scale, since there is no advantage in reducing the size of the object if it can conveniently be drawn full size on the sheet of drawing cloth or paper.

15. Symbols Used On Heating and Ventilating System Drawings

15-1. With a good working drawing and the knowledge of how to read and interpret it, you can develop patterns, fabricate components, and install entire heating and ventilating systems. Already in this chapter you have learned how to read and interpret lines, views, and dimensions used on working drawings, and in figure 62 you noticed symbols used on the drawings. Now let us examine the various symbols used for ducts, dampers, registers, grilles, and louvers.

15-2. **Symbols for Rectangular Ducts.** Duct symbols are used on working drawings for such purposes as distinguishing one duct from another; determining if a duct is round or rectangular; or determining if the duct is a supply, return, or exhaust line. Also, the direction of airflow, inlets and outlets, flexible connections, and turn vanes can be identified with symbols. In figure 71, you can see some of the symbols used for rectangular ducts.

15-3. *Duct size.* Height and width of a duct are determined by dimensions written on a section of the duct, as shown in *a* of figure 71. Remember that the first number will indicate the dimension of the visible side of the duct, regardless of whether it is a plan or elevation view. For example, if the drawing is an elevation view, the duct is 12" high and 20" wide.

15-4. *Duct, direction of flow.* This symbol, shown in *b* of figure 71, indicates the direction of flow through the duct. The symbol is not always used, since many duct systems are simple and the inlet and outlet openings will have direction of flow indicated with letters or arrows.

15-5. *Duct, exhaust section.* This symbol, shown in *c* of figure 71, is used to identify an exhaust opening in a duct, with the direction of flow indicated by a single diagonal and the letter E (exhaust). The arrow in this symbol *does not* indicate direction of flow but points out the size of the opening, which in this case is 12" x 20". Notice also in figure 71 that several other duct symbols are similar to this one except for letters and diagonal lines. The single diagonal line always indicates flow into the duct.

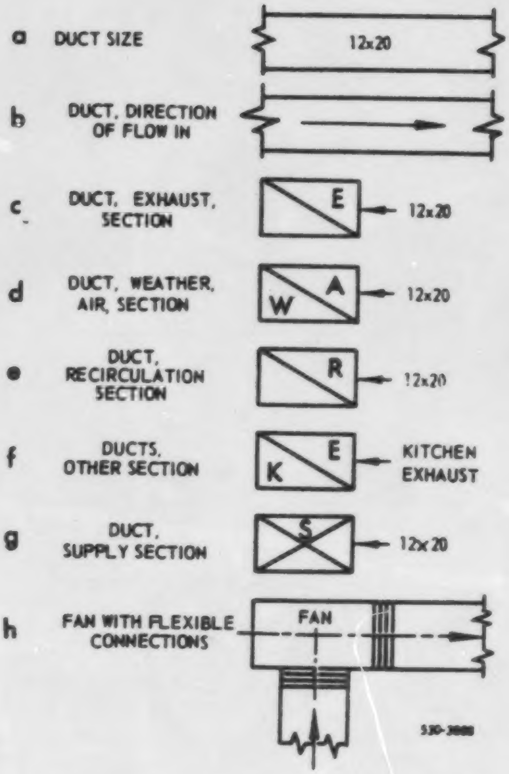


Figure 71. Symbols used with rectangular ducts.

15-6. *Duct, weather-air section.* This symbol, shown in *d* of figure 71, indicates a duct opening where inside air A and outside air W are flowing into the duct. These symbols may be found on a drawing of a duct which is the return air system to a furnace and which mixes outside air and inside air.

15-7. *Duct, recirculation system.* This symbol, shown in *e* of figure 71, is similar to the weather-air symbol except that only return air (designated by the letter R) is involved. This symbol will be found on most drawings that have a return air duct system to the furnace. If you look at figure 62, you can see a slight variation of the return air symbol where an arrow is used to indicate direction of flow instead of the letter R.

15-8. *Duct, other section.* This symbol, shown in *f* of figure 71, has a single diagonal to represent direction of flow, the letter E to represent exhaust, and the letter K to represent kitchen.

15-9. *Duct, supply section.* This symbol, shown in *g* of figure 71, has two diagonals which indicate the direction of flow from the duct. The letter S, which may or may not be used, simply

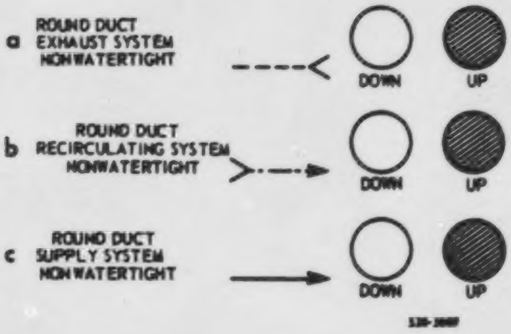


Figure 72. Symbols used for round ducts.

means supply. The arrow *does not* indicate direction of flow but points out the size of the duct, which in this case is 12" x 20". Remember that two diagonal lines represent a supply duct.

15-10. *Fan with flexible connections.* This symbol, shown in *h* of figure 71, is used to indicate the location of a fan or blower in a duct system. The arrows indicate the direction of airflow. Not enough of the system is shown in the illustration to indicate whether the fan is being used for exhaust purposes or for supply purposes; however, when this symbol is used on a working drawing you can determine its purpose by its location in the duct system.

15-11. The connector symbol (four parallel lines shown in *h* of figure 71) is also important to you as a sheet metal specialist because you are responsible for installation and maintenance of connectors. This symbol as used in figures 62, 63, and 64 represents an asbestos cloth connector between the furnace outlet and the supply duct. The same four-line symbol may be used to represent a regular canvas cloth connector if the location of the symbol is on the return air or intake side of the furnace.

15-12. **Symbols for Round Ducts.** Most of the round ducts you will encounter will be in kitchen exhaust systems and the heating and cooling ducts of family housing units.

15-13. *Round duct, exhaust system, nonwatertight.* The duct symbols, shown in *a* of figure 72, are used on working drawings to indicate a round nonwatertight exhaust duct such as that used with a hood to exhaust smoke and heat from a kitchen range. The broken line with the flared end (tail end of the broken arrow) is used on the plan views with the appropriate down or up symbol.

15-14. *Round duct, recirculating system, nonwatertight.* This symbol, shown in *b* of figure 72, is used on the plan views of working drawings or round return ducts such as the return air duct to furnaces. The appropriate up or down symbol should be identified with the broken line arrow as shown in the illustration.

15-15. *Round duct, supply system, nonwatertight.* This symbol, illustrated in *c* of figure 72, is used on the plan views of working drawings to indicate round supply ducts to components such as furnaces.

15-16. **Symbols For Turn Vanes.** The turn vane symbols, shown in figure 73, are used on working drawings to indicate the location of turn vanes inside of ducts. Vanes reduce the air resistance at elbows to permit the air to change direction with less turbulence; they are installed at the shop during fabrication of the elbows.

15-17. **Damper Symbols.** Dampers are deflecting or shutoff devices installed inside ducts to regulate the flow of air. Many dampers are manually operated and have handles that are accessible from outside the duct; however, some are motor operated for remote control and others operate automatically. Figure 74 shows six kinds of symbols that are used on working drawings for various dampers.

15-18. *Damper, blank off.* The symbol used for damper blank off (shutoff) is shown in *a* of figure 74. This device may be of the butterfly type, similar to *f* of figure 74, or it may be a sliding gate.

15-19. *Dampers, automatic.* This symbol is used for multiple blade dampers which are automatically operated. The symbol shown in *b* of figure 74 is for a motor-operated damper; when the damper is not motor operated, the symbol *will not* have the letter M. An example of a nonmotor-operated damper is a fire damper installed in a duct system; in case of fire, a fusible link will melt, and the spring loaded damper blades will close off the airflow through the duct.

15-20. *Damper, deflecting.* The deflecting damper symbols shown in *c*, *d*, and *e* of figure 74 represent similar dampers used to deflect airflow. The purpose of these dampers is to balance the airflow at a takeoff or branch in a duct.

15-21. *Damper, volume.* This symbol, shown in the two views in *f* of figure 74, is frequently used in drawings to show the location of volume

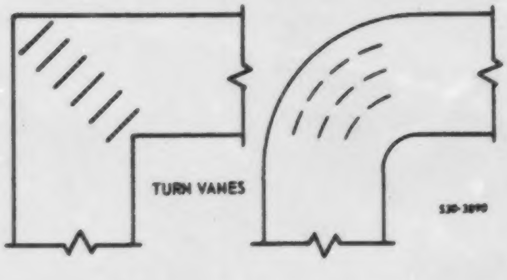


Figure 73. Symbols used for turn vanes.

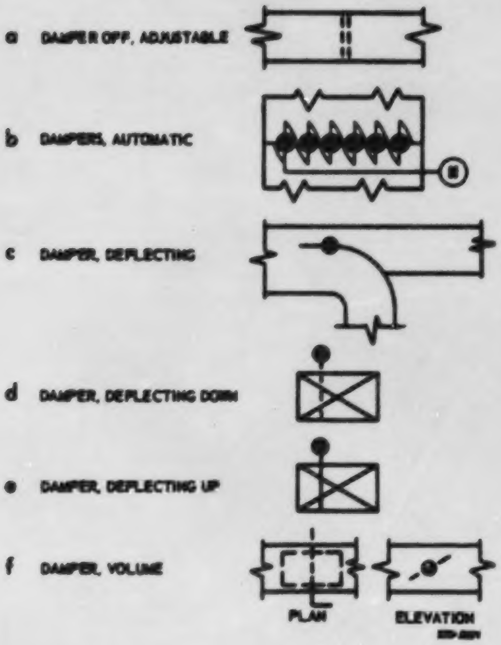

a DAMPER OFF, ADJUSTABLE
b DAMPERS, AUTOMATIC
c DAMPER, DEFLECTING
d DAMPER, DEFLECTING DOWN
e DAMPER, DEFLECTING UP
f DAMPER, VOLUME
PLAN
ELEVATION

Figure 74. Symbols used for dampers.

dampers in air ducts such as those used in heating or cooling systems. Notice the similarity of the plan and elevation views.

15-22. **Symbols for Registers.** Symbols used to indicate locations of registers on working drawings are shown in figure 75. In sheet metalwork, a register is a supply outlet for heating and cooling systems. The register is the portion of the duct system that covers the duct outlet. Registers are usually finished to match the room and often have turn blades to control the direction of airflow.

15-23. *Register, ceiling.* This symbol, shown in *a* of figure 75, is used to plan views to indicate the location of ceiling registers. The arrow and the two diagonals indicate a supply outlet. The other information shown indicates that the outlet is a ceiling register of the given dimension and airflow. The 700 cfm indicates a supply of 700 cubic feet of air per minute.

15-24. *Register, wall.* The symbols, shown as *b* thru *f* of figure 75, are similar except for specific uses. The basic symbol for a supply register is shown in *b;* the other symbols are variations identified by letters such as BR for the bottom register used near floor level, CR for a center register used about halfway between floor and ceiling level, and TR for a register used near ceiling level.

15-25. **Symbols For Grilles.** The symbols for grilles are the same as symbols for registers except for the identifying letters. For example, the letters BR identifying a bottom register would be changed to BG for a bottom grille. A grille consists of a plain or fancy framework of metal bars, wires, or louvers used to cover an opening such as the inlet of a return duct. Whether used at an inlet or outlet, a grille does not include deflectors or a regulating device.

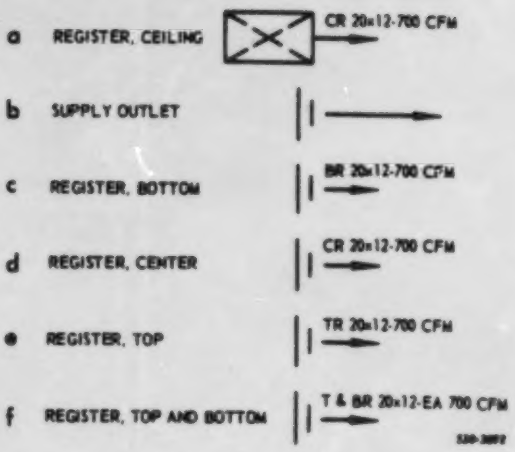

a REGISTER, CEILING
CR 20x12-700 CFM
b SUPPLY OUTLET
c REGISTER, BOTTOM
BR 20x12-700 CFM
d REGISTER, CENTER
CR 20x12-700 CFM
e REGISTER, TOP
TR 20x12-700 CFM
f REGISTER, TOP AND BOTTOM
T & BR 20x12-EA 700 CFM

Figure 75. Symbols for registers.

15-26. **Symbols For Louvers.** In figure 76, you can see two symbols which are used to identify louvers on working drawings. A louver is a series of sloping slats set in a frame or other opening to allow passage of air. In sheet metalwork, louvers are used as ventilating slits to cover inlet and outlet openings in duct systems or exhaust fans. Louvers can be stationary, manual, or automatic type.

15-27. *Louver opening location symbol.* Location of a louver on a working drawing is identified by the symbols shown in *a* of figure 76. This symbol identifies the location only and does not designate the type of louver. The arrow indicates the direction of airflow. Notice that the louver symbol has two vertical lines, the same as for registers.

15-28. *Louver and screen.* The symbol shown in *b* of figure 76 designates a weather or air in-

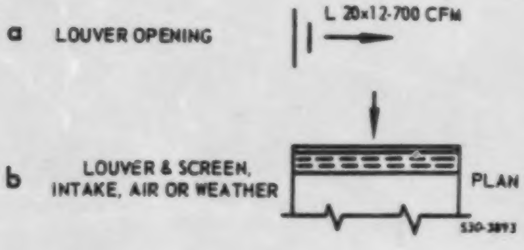

a LOUVER OPENING
L 20x12-700 CFM
b LOUVER & SCREEN, INTAKE, AIR OR WEATHER
PLAN
530-3893

Figure 76. Symbols for louver and opening.

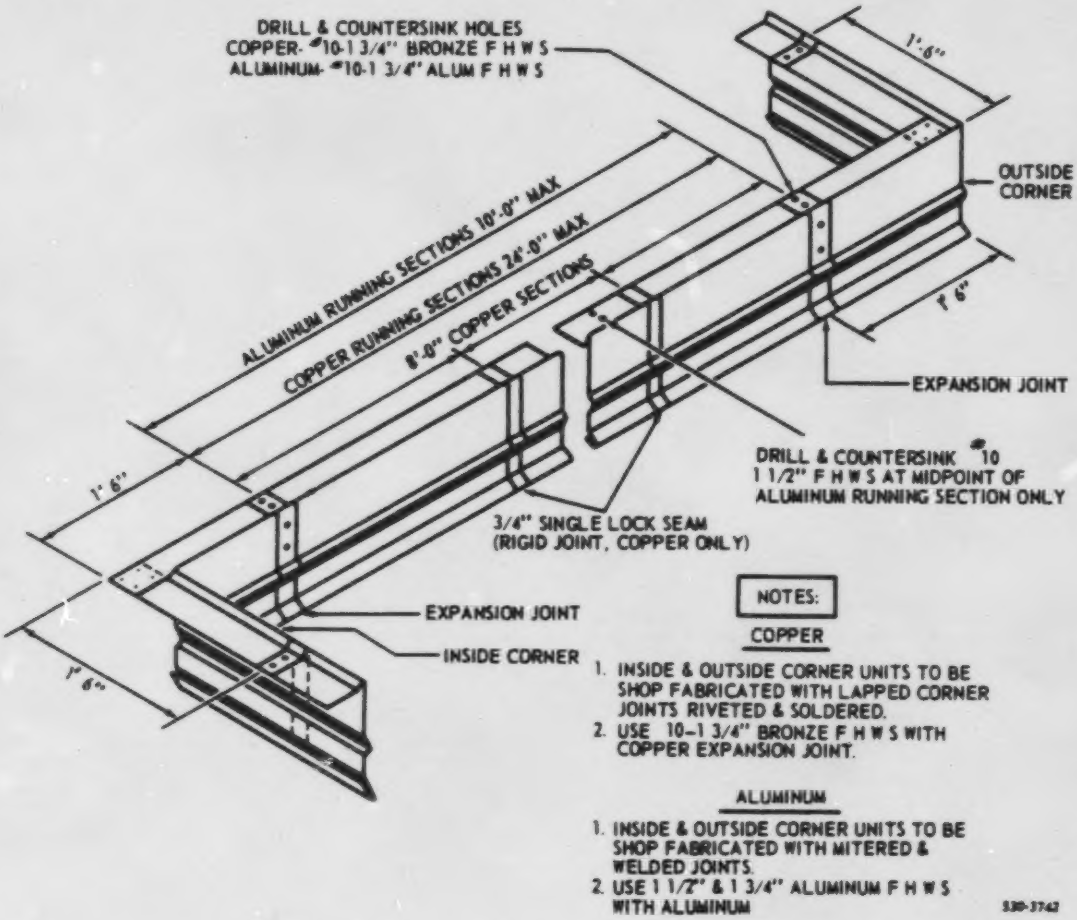
take louver and screen. An example of the use of this symbol would be in a plan view of a duct system such as the weather air intake of the return ducts to a furnace. This symbol represents the type of louver used at the intake shown in *d* of figure 71.

16. Notes and Specifications

16-1. Specifications for sheet metalwork and other construction projects are used to supplement the information on working drawings. They are written descriptions of the standards to be maintained, and they state specifically all the factors not shown on the drawings. Notes and specifications have a similar purpose, but notes are condensed versions which are written on the working drawings.

16-2. **Notes.** The notes shown on drawings are similar to portions of the specifications and are used to explain the drawing. Examples of notes are contained in figures 77 and 78. Figure 77 shows a pictorial view of the gravel stop and fascia used around the edges of a flat roof. Figure 78 is a detail view of expansion joints used with the gravel guard and fascia. Notice that the drawing serves as a fabrication guide for either aluminum or copper construction, and that the notes indicate that bronze flathead wood screws are to be used if the gravel guard is made of copper sheets and that aluminum flathead screws are to be used with aluminum sheets.

16-3. **Specifications.** The specifications for sheet metalwork should clearly indicate quality and quantity of materials, the methods of construction, the nature of the workmanship, the manner of conducting the work, and the general conditions and agreements. Specifications consist of two types, general and specific, and much time and thought are given to their preparation to make sure that every detail is covered. The specific types concern individual projects, such


DRILL & COUNTERSINK HOLES
COPPER- #10-1 3/4'' BRONZE F H W S
ALUMINUM- #10-1 3/4'' ALUM F H W S
1'-6''
OUTSIDE CORNER
ALUMINUM RUNNING SECTIONS 10'-0'' MAX
COPPER RUNNING SECTIONS 24'-0'' MAX
8'-0'' COPPER SECTIONS
1' 6''
EXPANSION JOINT
DRILL & COUNTERSINK #10
1 1/2'' F H W S AT MIDPOINT OF
ALUMINUM RUNNING SECTION ONLY
1' 6''
3/4'' SINGLE LOCK SEAM
(RIGID JOINT, COPPER ONLY)
EXPANSION JOINT
INSIDE CORNER
1' 6''
530-3742

NOTES:

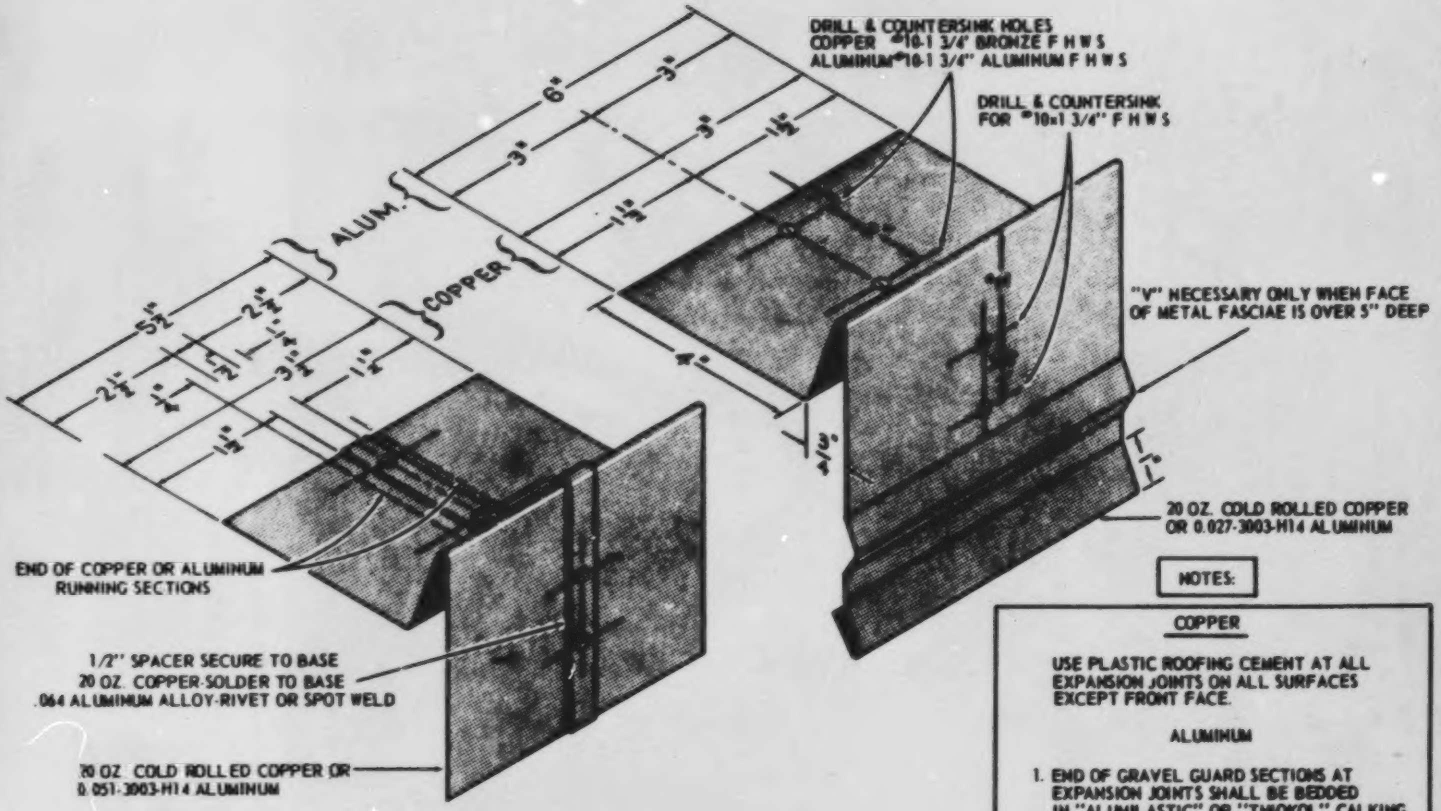
COPPER

1. INSIDE & OUTSIDE CORNER UNITS TO BE SHOP FABRICATED WITH LAPPED CORNER JOINTS RIVETED & SOLDERED.
2. USE 10-1 3/4'' BRONZE F H W S WITH COPPER EXPANSION JOINT.

ALUMINUM

1. INSIDE & OUTSIDE CORNER UNITS TO BE SHOP FABRICATED WITH MITERED & WELDED JOINTS.
2. USE 1 1/2'' & 1 3/4'' ALUMINUM F H W S WITH ALUMINUM

Figure 77. Gravel stop and fascia.


DRILL & COUNTERSINK HOLES
COPPER #10-1 3/4" BRONZE F H W S
ALUMINUM #10-1 3/4" ALUMINUM F H W S
DRILL & COUNTERSINK
FOR #10x1 3/4" F H W S
6"
3"
3"
3"
1½"
1½"
ALUM.
COPPER
COPPER
5½"
4"
1"
"V" NECESSARY ONLY WHEN FACE
OF METAL FASCIAE IS OVER 5" DEEP
20 OZ. COLD ROLLED COPPER
OR 0.027-3003-H14 ALUMINUM
END OF COPPER OR ALUMINUM
RUNNING SECTIONS
1/2" SPACER SECURE TO BASE
20 OZ. COPPER-SOLDER TO BASE
.064 ALUMINUM ALLOY-RIVET OR SPOT WELD
20 OZ. COLD ROLLED COPPER OR
0.051-3003-H14 ALUMINUM

NOTES:

COPPER

USE PLASTIC ROOFING CEMENT AT ALL EXPANSION JOINTS ON ALL SURFACES EXCEPT FRONT FACE.

ALUMINUM

1. END OF GRAVEL GUARD SECTIONS AT EXPANSION JOINTS SHALL BE BEDDED IN "ALUMILASTIC" OR "THIOKOL" CALKING MATERIAL, APPLIED TO ALL SURFACES EXCEPT TO FRONT FACE.
2. SHOP SCRIBE RUNNING SECTIONS 2" FROM EACH END FOR GAUGING EXPANSION SPACE AT EXPANSION JOINTS.
3. REINFORCE FELT STRIPPING AT EXPANSION JOINTS WITH AN 8"x12" FABRIC WITH FLAT TUCK OVER EACH EXPANSION JOINT.

530-3743

Figure 78. Detail of expansion joint.

as a contract job for construction of a new building where the specifications are definite rather than general. Specific specifications cover such items as the quality of the material, details of construction, working drawings, and other special features.

16-4. General specifications are, as the name implies, general in nature and are applicable to more than one construction job. The Corps of Engineers prepares general specifications for all types of military construction, and these are indexed in AFR 0–4. In this regulation, you can find the Guide Specifications For General Sheet Metalwork listed as CE–220.08. These general specifications cover all kinds of sheet metals, fastening methods, soldering, welding, and seaming and fabrication specifications for different sheet metal components.

16-5. This paragraph concerns general specifications from CE–220.08 which are related to the gravel stop and fascia illustrated in figures 77, 78, and 79. Gravel stops and fasciae are formed of sheets of standard stock lengths not less than 8 feet long; they are shop fabricated from one piece of material of suitable width. Note in figure 79 that the gravel stop and fascia extend above the roof line. Gravel stops and fasciae must be provided with concealed splice plate or other suitable slip-joining member designed to allow for expansion at specified intervals. Expansion and contraction joints must be one-piece assemblies around internal and external corners, and the allowance for expansion cannot be less than ¼ inch at each joint. Splice plates or other concealed items for securing the joints must lap the gravel stops and fasciae not less than 4 inches. The inner flange of the gravel stops and fasciae must extend not less than 4 inches onto the roof over the felt roofing plies and must be fastened to the edge nailing strips with nails spaced not over 3 inches on centers. Where the fascia part of the gravel stop is 5 inches or more in width, the lower edge must be hooked at least ¾ inch over edge drip strips and bent outward at an angle of 45° to form a drip.

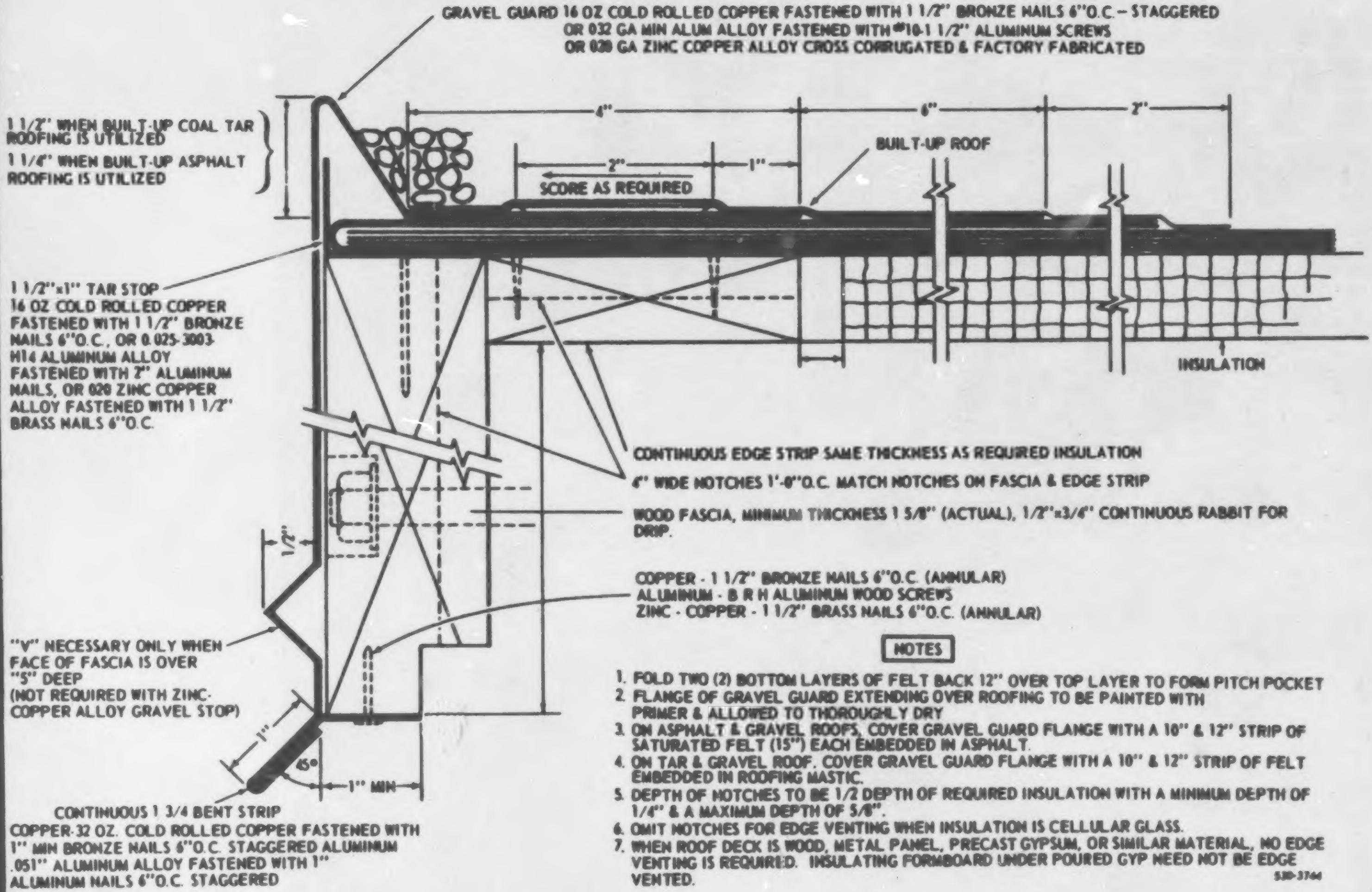
17. Working Drawings of Sheet Metalwork

17-1. Figures 77, 78, and 79 are working drawings for fabrication and installation of gravel stops and fasciae for buildings with flat roofs. With these drawings and dimensions of the buildings, your shop can fabricate exact replacements. These working drawings are considered a part of the specific specifications and must be closely followed for fabrication and installation procedures.

17-2. As you examine the pictorial view shown in figure 77, you can quickly see the overall shape of the gravel stop and fascia (sometimes called a gravel guard and fascia). Further examination will indicate additional information such as dimensions of the running sections and how the corners are fabricated.

17-3. From the detail views of the expansion joint shown in figure 78 you can see fabrication information that was not included in figure 77. The detail views show the construction of the expansion joint, which is made of three pieces of metal—the base, spacer, and the face which matches the fascia. Other information shown includes such details as the gage of metal to use, dimensions, and special notes.

17-4. Figure 79 is a cross section detail view of the gravel guard and tar stop. In this view you can see in detail how the installation is made, including such items as the gravel guard, tar stop, lower support strip, and felt strips. This detail view also illustrates the method of nailing the tar stop and lower bent strip support. The abbreviation "OC" in the notes means on center.


GRAVEL GUARD 16 OZ COLD ROLLED COPPER FASTENED WITH 1 1/2" BRONZE NAILS 6"O.C. – STAGGERED
OR 032 GA MIN ALUM ALLOY FASTENED WITH #10-1 1/2" ALUMINUM SCREWS
OR 020 GA ZINC COPPER ALLOY CROSS CORRUGATED & FACTORY FABRICATED
1 1/2" WHEN BUILT-UP COAL TAR ROOFING IS UTILIZED
1 1/4" WHEN BUILT-UP ASPHALT ROOFING IS UTILIZED
4"
6"
2"
2"
1"
SCORE AS REQUIRED
BUILT-UP ROOF
1 1/2"x1" TAR STOP
16 OZ COLD ROLLED COPPER FASTENED WITH 1 1/2" BRONZE NAILS 6"O.C., OR 0.025-3003-H14 ALUMINUM ALLOY FASTENED WITH 2" ALUMINUM NAILS, OR 020 ZINC COPPER ALLOY FASTENED WITH 1 1/2" BRASS NAILS 6"O.C.
INSULATION
CONTINUOUS EDGE STRIP SAME THICKNESS AS REQUIRED INSULATION
4" WIDE NOTCHES 1'-0"O.C. MATCH NOTCHES ON FASCIA & EDGE STRIP
WOOD FASCIA, MINIMUM THICKNESS 1 5/8" (ACTUAL), 1/2"x3/4" CONTINUOUS RABBIT FOR DRIP.
1/2"
COPPER - 1 1/2" BRONZE NAILS 6"O.C. (ANNULAR)
ALUMINUM - B R H ALUMINUM WOOD SCREWS
ZINC - COPPER - 1 1/2" BRASS NAILS 6"O.C. (ANNULAR)
"V" NECESSARY ONLY WHEN FACE OF FASCIA IS OVER "5" DEEP (NOT REQUIRED WITH ZINC-COPPER ALLOY GRAVEL STOP)
1"
45°
1" MIN
CONTINUOUS 1 3/4 BENT STRIP
COPPER-32 OZ. COLD ROLLED COPPER FASTENED WITH 1" MIN BRONZE NAILS 6"O.C. STAGGERED ALUMINUM .051" ALUMINUM ALLOY FASTENED WITH 1" ALUMINUM NAILS 6"O.C. STAGGERED
530-3744

NOTES

1. FOLD TWO (2) BOTTOM LAYERS OF FELT BACK 12" OVER TOP LAYER TO FORM PITCH POCKET
2. FLANGE OF GRAVEL GUARD EXTENDING OVER ROOFING TO BE PAINTED WITH PRIMER & ALLOWED TO THOROUGHLY DRY
3. ON ASPHALT & GRAVEL ROOFS, COVER GRAVEL GUARD FLANGE WITH A 10" & 12" STRIP OF SATURATED FELT (15") EACH EMBEDDED IN ASPHALT.
4. ON TAR & GRAVEL ROOF, COVER GRAVEL GUARD FLANGE WITH A 10" & 12" STRIP OF FELT EMBEDDED IN ROOFING MASTIC.
5. DEPTH OF NOTCHES TO BE 1/2 DEPTH OF REQUIRED INSULATION WITH A MINIMUM DEPTH OF 1/4" & A MAXIMUM DEPTH OF 5/8".
6. OMIT NOTCHES FOR EDGE VENTING WHEN INSULATION IS CELLULAR GLASS.
7. WHEN ROOF DECK IS WOOD, METAL PANEL, PRECAST GYPSUM, OR SIMILAR MATERIAL, NO EDGE VENTING IS REQUIRED. INSULATING FORMBOARD UNDER POURED GYP NEED NOT BE EDGE VENTED.

Figure 79. Detail of gravel and tar stop.

Sheet Metal Layout

AS A SHEET metal specialist, you will be using the different methods of layout to make flat patterns from working drawings and blueprints. Flat patterns are developed using one or more of three layout methods—parallel line method, radial line method, and triangulation method.

2. These different layout meehods are needed to develop flat patterns for different shapes of sheet metal components. For example, to select a layout method, you need to know why true lengths are different from tapered lengths; why parallel lines are used to lay out square and rectangular ducts; why triangles are important when laying out transitions; and why radial lines are used when laying out cone-shaped or pyramid-shaped components. These layout methods are important to you, since they will be used to develop patterns when you fabricate new or replacement components.

3. The layout methods learned in this chapter will be used later in this course when you study the fabrication, installation, and repair of sheet metal components. In the fabrication and repair of different components, you will be developing patterns for such items as round ducts, square ducts, rectangular ducts, elbows, offsets, ventilators, and transitions. First let us consider how to make flat patterns from working drawings.

18. Making Patterns for Sheet Metal Components

18-1. Working drawings in most cases are drawings that you, your supervisor, or a draftsman have made from prints, from sketches, or from a component that is to be replaced. Good drawings include correct and accurate measurements, which are essential if you are to make an accurate layout.

18-2. When you are laying out a pattern for a component, regardless of the source of its description, you will need to determine the layout method to be used. A drawing or print will show the dimensions of the component; however, if a drawing is not available and a duplicate or like item is to be made, you will have to take measurements and make a sketch of the component on a piece of paper. The sketch should include all needed descriptive information.

18-3. When using a blueprint or working drawing, you can get a description of the item from the plan view and/or elevation view. If the component is shown only in the plan view or the elevation view, the measurement will give a good description. However, if detail views are shown on a drawing or print, they will illustrate the component much better.

18-4. Obtaining measurements and description of the component is the first step in making a flat pattern. This is where the blueprint or drawing is important, since it is the guide for developing patterns for the components to be made. In this chapter, you will learn how other plan views and elevation views are used to develop flat patterns for sheet metal components.

18-5. **Flat Pattern Layouts.** Flat pattern layouts are drawings which show the shape of components in the flat or stretched out position. In Chapters 2 and 4, you studied many kinds of figures such as triangles, squares, rectangles, prisms, cones, and pyramids. Now in figure 80, view A, you can see a section of a rectangular sheet metal duct. View B shows a flat pattern or stretchout of the same duct. Note that the strechout is a series of rectangles. In figure 81, you can see the stretchout of a square duct. In figure 82, view A, you can see the half plan and elevation views of a round duct, and in view B the stretchout of a round duct (cylinder).

18-6. Patterns for rectangular, round, and square ducts are developed using the parallel line method. Cone- and pyramid-shaped components are developed using the radial line method. Transitions such as square to round and rectangular to round are developed using the triangulation layout method.

18-7. When laying out patterns of objects such as straight ducts that are round, square, or rectangular, a parallel line stretchout (such as that

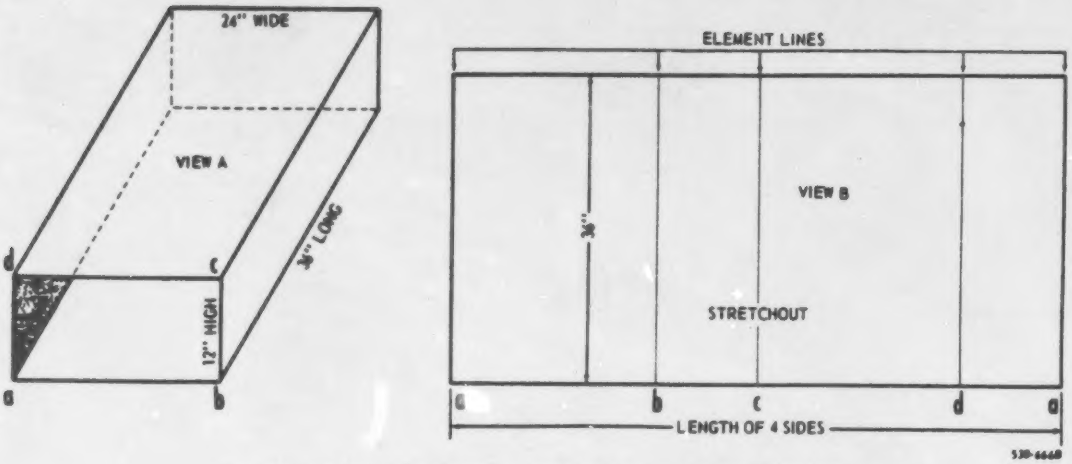


Figure 80. Parallel line pattern development for a rectangular duct.

shown in figures 80, 81, and 82) can be used to show the shape of the part. However, this simple type of stretchout *cannot* be used to lay out round, square, or rectangular objects that are larger on one end than the other or that have bends such as 45° or 90° elbows. These more complex flat pattern layouts involve additional layout methods such as the radial line method and triangulation method. The three methods are discussed in more detail in the following paragraphs.

18-8. When developing patterns using the three layout methods you will be using layout tools you learned about in Chapter 3, such as T-square, triangle, divider, compass, and drawing board.

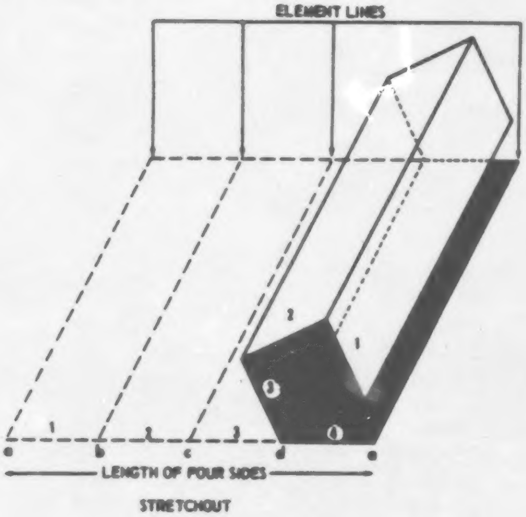


Figure 81. Parallel line pattern development for a square duct.

18-9. **Parallel Line Layout Method.** The parallel line method of layout is used to develop patterns for components that have parallel sides. True lengths of element lines play an important part in parallel line development. Element lines as shown in figures 80, 81, and 82 are equally spaced lines used to lay out the pattern. In parallel line development, all element lines are parallel or perpendicular to each other. The length of the duct section (or true length) is indicated by the length of the element lines. True length does not include the seam allowances.

18-10. Now let us develop patterns for the square, round, and rectangular ducts shown in figures 80, 81, and 82, starting with view A in figure 80. As you see, sides *ab* and *cd* are the same width, and *bc* and *da* are the same width. To lay out a pattern for view A, the length, height, and width of the four sides are needed. Suppose the duct measurements are 24 inches wide, 12 inches high, and 36 inches long (24" x 12" x 36" long). The flat pattern is laid out by drawing a straight line (stretchout) equal to the perimeter of the four sides. Element line *a* on the left is drawn perpendicular to the stretchout line, which is 36 inches long. Element line *b* is drawn 24 inches from element line *a* and parallel to element line *a*. Element line *c* is drawn 12 inches from element line *b* and parallel to element line *b*. Element line *d* is drawn 24 inches from element line *c* and parallel to element line *c*. Now a second element line *a* is drawn 12 inches from element line *d* and parallel to element line *d*. All the element lines are 36 inches long (the true length of the duct). The element lines should be joined across the top to complete the pattern. It is a good practice to check the pattern for correct dimensions and squareness after it has been developed. This pattern can be formed into a

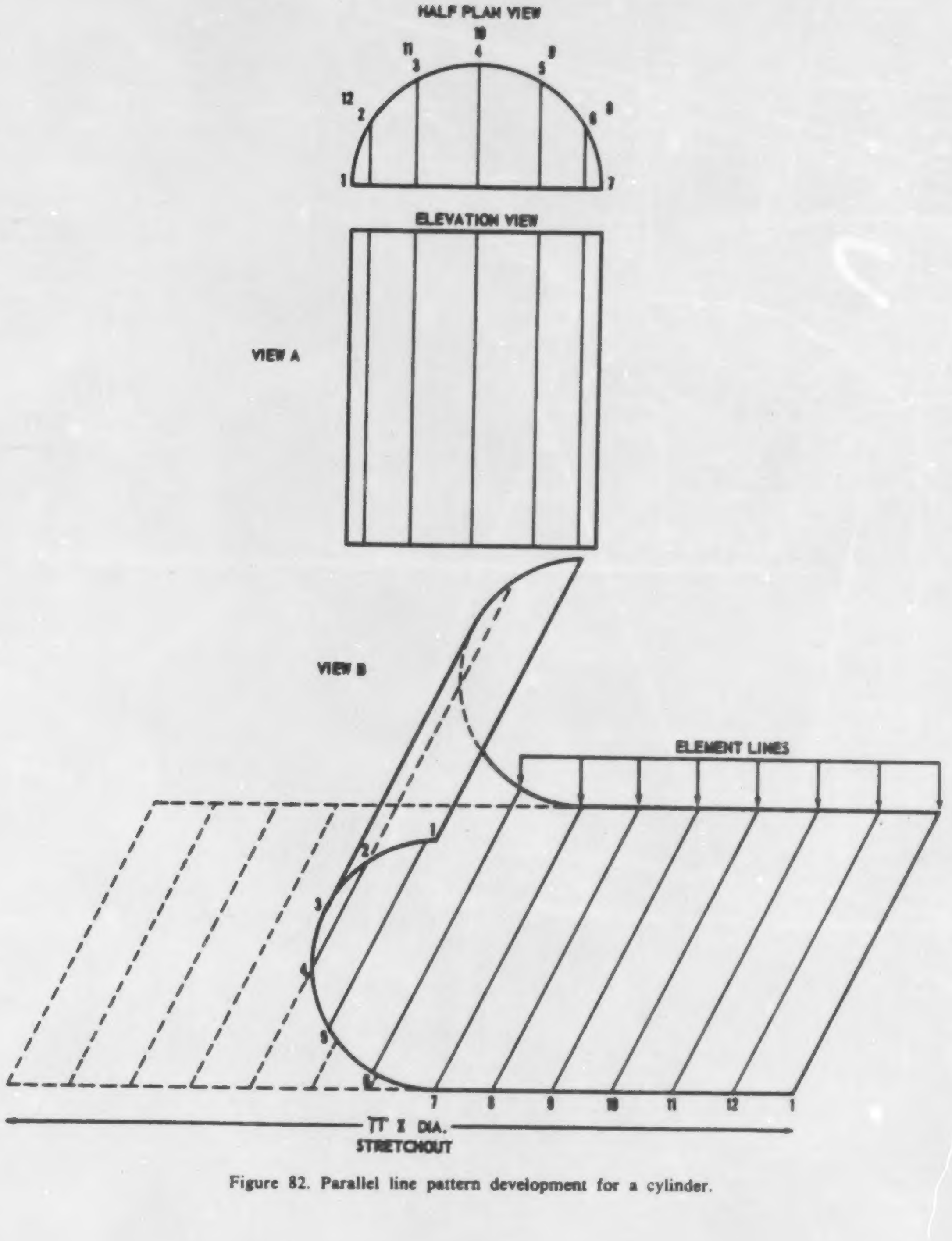

HALF PLAN VIEW
10
11
9
3
4
5
12
2
6
8
1
7
ELEVATION VIEW
VIEW A
VIEW B
ELEMENT LINES
1
2
3
4
5
6
7
8
9
10
11
12
1
π X DIA.
STRETCHOUT

Figure 82. Parallel line pattern development for a cylinder.

rectangular-shaped duct by breaking (bending the metal 90°) at element lines *b*, *c*, and *d*.

18-11. Figure 81 shows the stretchout of a square duct. The parallel line layout method is used to develop square duct patterns the same as those for rectangular ducts. The stretchout length is the perimeter or the sum of the four sides: 1, 2, 3, and 4. The length of the element lines is determined by the true length of the duct. To form the stretchout into a square duct, the element lines *b*, *c*, and *d* are broken into 90° angles.

18-12. View A in figure 82 includes both the plan view and elevation view for a round duct (cylinder). The half plan shows part of the cylinder as you would see it looking from the top down. The half plan arc is divided into 12 equal parts, resulting in 13 element lines. Notice how the half plan view is used to represent a whole plan view and is divided into half the spaces of the plan view. In view B of figure 82, which is the pattern for view A, notice that the stretchout is divided into 12 equal parts, and the element lines are parallel to each other. Remember that the element lines are the true length of the duct you are laying out. View B also represents view A as it would look stretched out in a flat pattern. To determine the length of the stretchout line for view B, use the circumference formula you learned in Chapter 2—(πd): multiply the diameter of the duct by 3.1416. The stretchout line is divided into equal parts; in this case we will use 12 parts. This pattern is formed by rolling, as shown in view B of figure 82.

18-13. Now that you have developed simple patterns using parallel lines, let us proceed to the development of parallel line patterns that require more accuracy and thought; for example, a pattern for a round pipe which has a 30° miter line. As you recall, a plan view and elevation view are needed to determine the length of the element lines. Line CD in view A of figure 83 is a miter line which will require element lines of different lengths. Where element lines are not the same length, a more accurate pattern can be made if additional element lines are drawn—the more the better. Using a T-square on the edge of the drawing board, draw line AB as shown in view A. Using a T-square and triangle, elevate lines AC and BD (drawn 90° to line AB). To accomplish line CD, draw it 30° to line BD. This can be done with a protractor or 30°-60° triangle. The center of line AB in view A can be found with a rule or by bisecting line AB with dividers or compass. Draw the arc of the half plan view, using the midpoint of line AB as the center. Draw a centerline perpendicular to line AB through the midpoint. Draw this perpendicular up to the miter line and down to the half plan arc. This centerline is identified as element line 4-10. The arc of the half plan is divided into three equal parts on both sides of element line 4-10. After this, element lines 2-12, 3-11, 5-9,

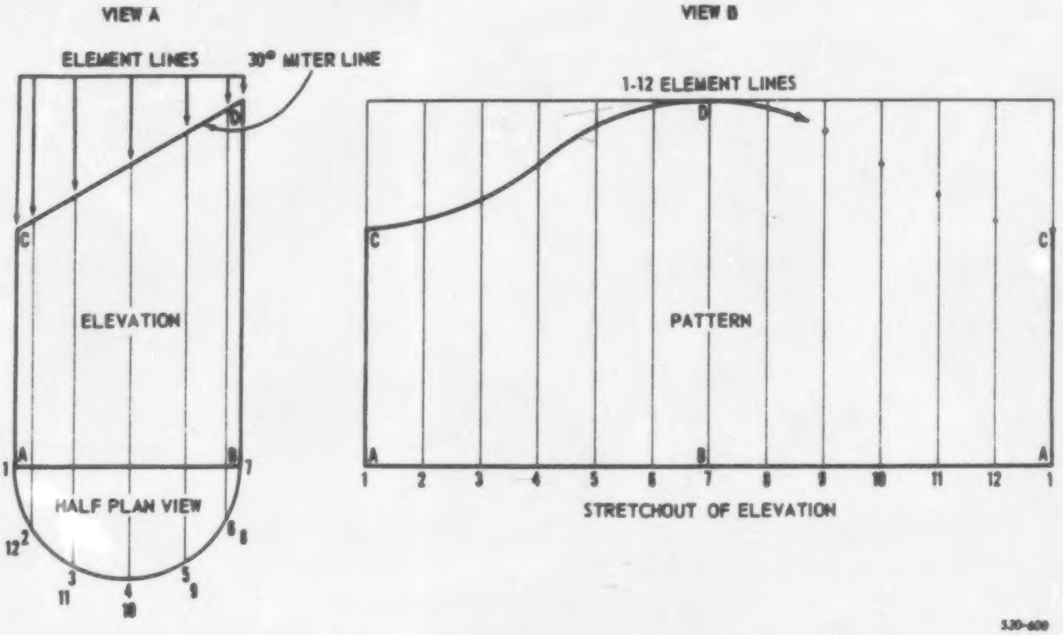


Figure 83. 30° miter pattern development.

and 6-8 are elevated through line AB to miter line CD.

18-14. The next step is to lay out the flat pattern as shown in view B of figure 83. The T-square is used to draw line ABA, which is the stretchout line of the cylinder. If line ABA in view B is drawn straight across from line AB in view A, the length of the element lines can be easily transferred by use of a T-square. Next, divide line ABA in the stretchout into 12 equal parts by element lines, and transfer the length of the elevation view element lines to the corresponding number in the stretchout. The length of the element lines can be transferred by using dividers, compass, or T-square. After the length of each element line in the stretchout is established, the points are connected by using an irregular (French) curve. Now we have a pattern of a cylinder with a miter line. This is the same pattern that we used in figure 56 to make a template. Notice that element points 1 through 7 represent one-half of the stretchout; element points 7 through 12 back to 1 represent the other half of the pattern. Point 1 is the seam line, since it is the starting of the point numbering. All seam allowances are made at point 1, which is line AC on either side of the stretchout. It is a good practice to cut patterns out and tape them together to see the finished product.

18-15. *Elbows.* Another important article used extensively in sheetmetal work is the multiple round elbow—multiple meaning more than one, and elbow meaning turned or bent at an angle. The elbows that you will make are constructed from a number of pieces of metal called gores, which are fastened together. It is important to remember that when more gores are used in the construction of an elbow, the resistance to airflow will be less. The elbow with five gores, shown in figure 85, will have less air resistance than the three-gore elbow shown in figure 84. Elbows are used to connect straight lengths of pipe that run in different directions. For example, suppose you have two lengths of round air duct with one running vertically between the wall studs and the other running horizontally between the floor joists. An elbow is needed to connect these two ducts so that the flow of air will pass from one section to the other.

18-16. The elevation view of a three-piece 90° elbow is shown in figure 84. Study the illustration and learn the names of the parts and the meaning of the symbols. Such terms as throat, heel, cheek, angle, diameter, and radius will be used when elbows are discussed in this text and when you are fabricating elbows in the shop. Notice that big R is the radius of the heel and little r is the radius of the throat. The diameter is represented by big D. The diameter, number of section, throat radii, and shape of elbows will have no effect upon the principle involved in the drawing of patterns. An important step necessary before pattern development can begin is the construction of the true miter lines. In figure 84, you can see these miter lines and the various parts of an elbow.

18-17. In figure 85, you can see the various steps necessary in developing true miter lines for 90° elbows. As you observe each, notice that regardless of the number of parts (gores) in the elbow, the miter lines are constructed by dividing the 90° arc into the desired number of equal parts. Also notice that there is one less miter line than the numbered sections. For example, in

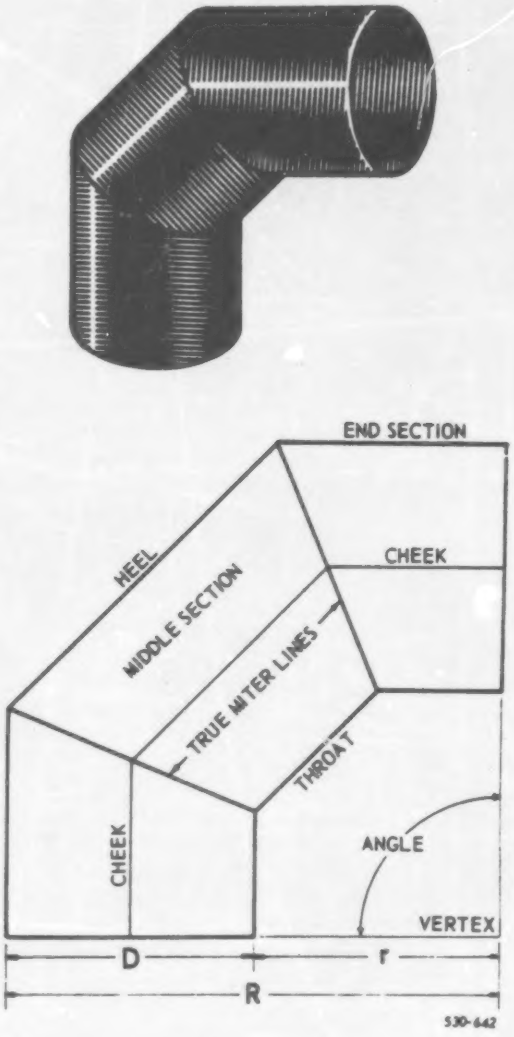


Figure 84. Parts of an elbow.

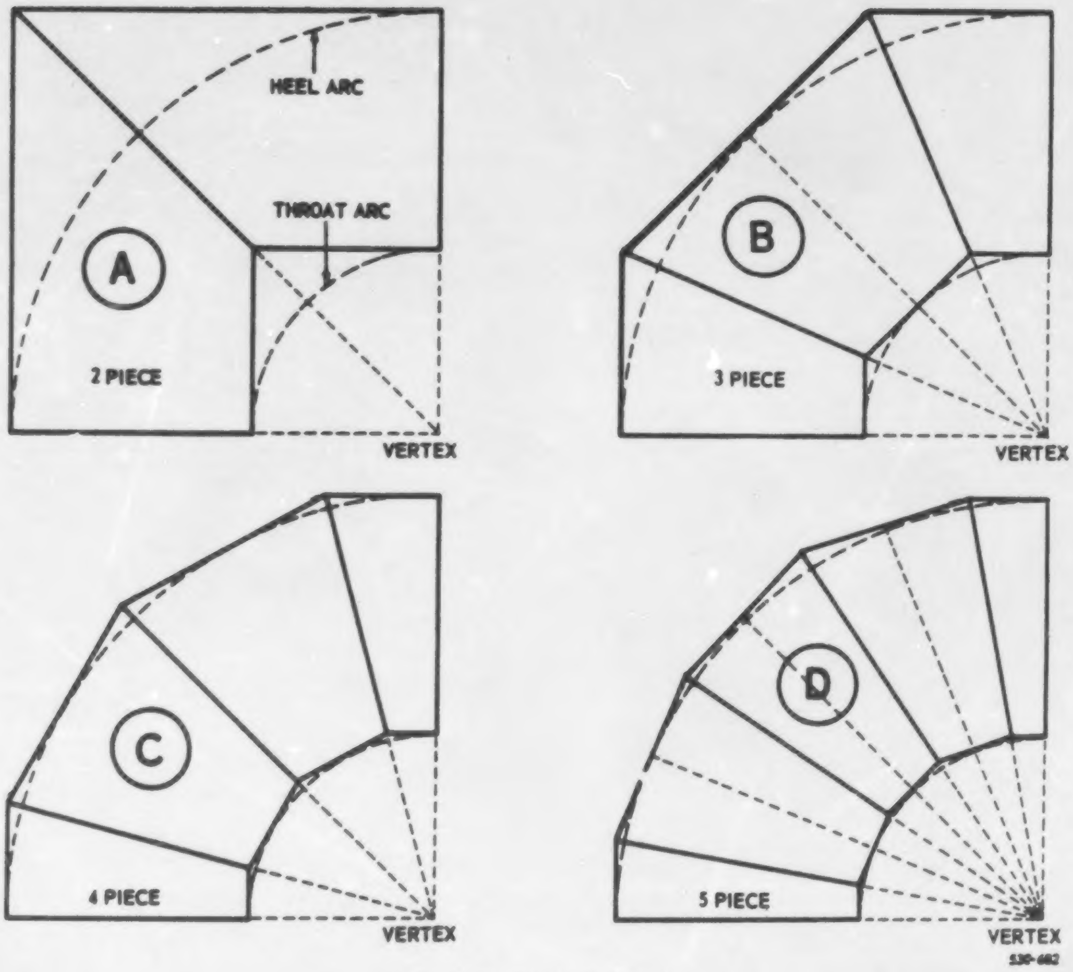


Figure 85. True miter lines.

view D the five-piece elbow has only four miter lines (The dark lines are the miter lines.)

18-18. To construct the miter lines in view A of figure 85, you must bisect the arc, then draw a line from the point of bisection to the vertex of the angle. You can use a compass or dividers to divide the angle. When you are drawing miter lines for elbows (as shown in views B, C, and D), a simple formula is used. Multiply the number of pieces (gores) in the elbow by 2 and subtract 2. For example, in view B a three-piece elbow is desired, so 3 × 2 = 6 and 6 − 2 = 4. Therefore, the elevation view will be divided into four equal segments, with two segments on each side of the 45° bisecting line. As you can see, this formula provides more segments than pieces required. The general practice is to allow one segment for each end piece and two segments each for the remaining pieces. Thus, in view B there will be two miter lines. Using the formula for view D, which has five pieces, 5 × 2 = 10 and 10 − 2 = 8, the elevation view will be divided into eight equal segments, with four segments on each side of the 45° bisecting line. Thus, view D will have four miter lines when you allow one segment for each end piece and two segments each for the remaining pieces.

18-19. Now let's use miter lines to develop a pattern. Suppose the drawing or blueprint requires a 90° elbow with a 6-inch diameter and a 3-inch throat radius. To develop the pattern as shown in figure 86, first draw the elevation view so as to construct a right angle, and then draw heel and throat arcs from the vertex. The heel radius for any size elbow is the sum of the diameter of the elbow and the throat radius.

18-20. The miter lines are drawn by connecting the vertex to points stepped off on the heel arc, which divides arc AC into eight equal segments or spaces. Now draw the dark miter lines

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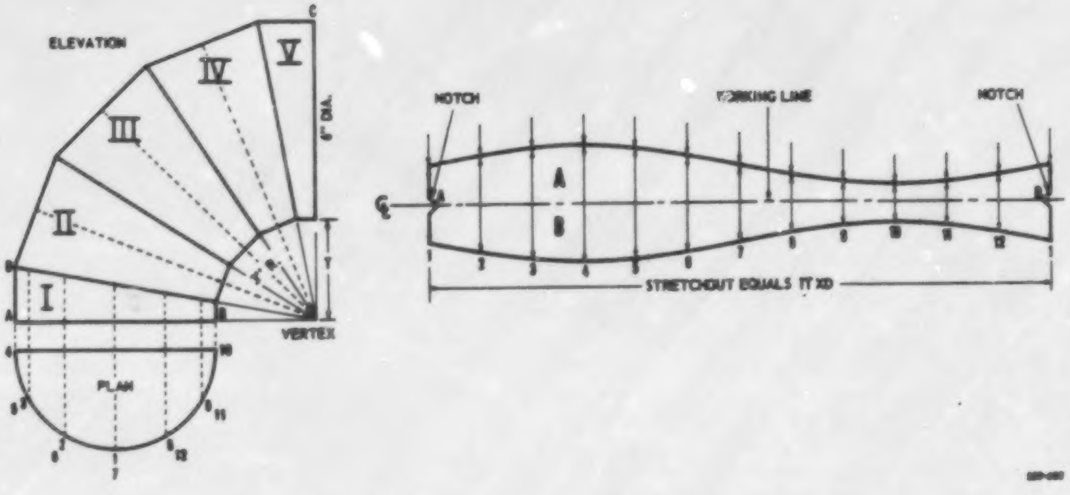


Figure 86. A five-piece elbow pattern development.

to make pieces I and V each equal to one segment on the heel arc, and pieces II, III, and IV equal to two segments. Drawing these miter lines completes the elevation view.

18-21. Using AB in the elevation view of figure 86 as the base line, construct the half plan view in a similar manner, as shown in figure 83. The greater the number of element lines and spaces you use, the more accurate the pattern will be.

18-22. To draw the stretchout shown in figure 86, first draw the working line, then divide into the same number of element lines and spaces as contained in the half plan view, which in this case is 12 spaces and 13 element lines. From the 13 points on the working line, draw element lines on both sides of the working line and number as shown in figure 86. The beginning and ending numbers in the half plan and stretchout designate the location of the seam in the finished elbow. Generally, the best location for a seam on an elbow is on the cheek. However, for appearances, you may want the seam on the throat or heel.

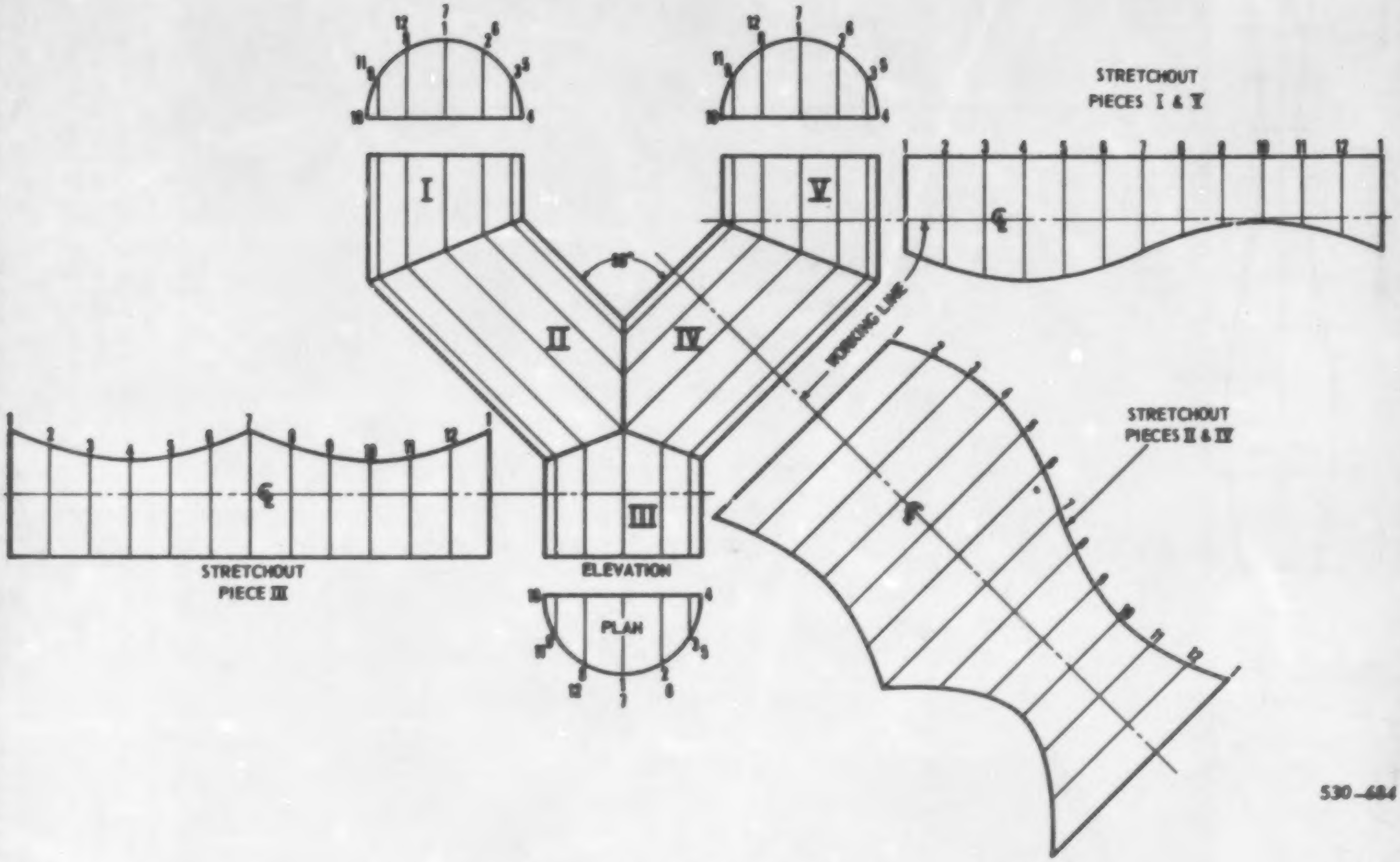
18-23. To determine the length of the element lines *on each side* of the working line, use a compass to transfer the length of each element line located between line AB and true miter line D in the elevation view. Transfer this distance to the stretchout by placing the sharp point of the compass on the working line, making two arcs (one above and one below) to indicate the total length of the element line. Make sure the element line numbers correspond. An irregular (French) curve is used to connect these arcs with smooth curved lines.

18-24. The stretchout shown in figure 86 is the pattern for one whole piece or gore of the elbow shown in the elevation view. The stretchout is used to make pieces II, III, and IV. Side A or one-half of the pattern is used to make piece I, and side B is used to make piece V; however, since they are identical they can be used for either end of the elbow. If the pattern is notched on both ends of the working line, alignment will be much easier when you transfer the pattern to metal. Elbows of different angles can be made by using various combinations of the pattern.

18-25. *Y-branch.* The Y-branch shown in figure 87 is made in five individual pieces, numbered I, II, III, IV, and V. When these five pieces are fastened together, the single duct is divided into two ducts of the same diameter. Y-branches can also be designed to connect different sizes of ducts. The miter lines and the angles at which these pieces meet may vary from job to job. Because of this, you may have to make as many as five different patterns, one for each piece shown in the elevation view.

18-26. In Y-branch pattern development, you will repeat some of the steps used to lay out elbows. From the elevation view of a Y-branch, you can obtain the true lengths of the element lines. First, draw the elevation view so you can determine the shape of the five pieces or gores; then draw the half plan view and divide into an equal number of spaces. From the 13 numbered points, the numbered element lines are projected through each section of the elevation view. This gives you the true lengths of the element lines for each piece (gore). Stretchouts for each piece are drawn as shown in the illustration, and the pattern is developed in the same manner as in figure 86.

18-27. *T-joint.* You have seen that to develop a stretchout pattern by the parallel line method,


STRETCHOUT
PIECES I & V
I
II
III
IV
V
90°
WORKING LINE
STRETCHOUT
PIECES II & IV
℄
STRETCHOUT
PIECE III
ELEVATION
PLAN
1
2
3
4
5
6
7
8
9
10
11
12

530–684

Figure 87. Y-branch development.

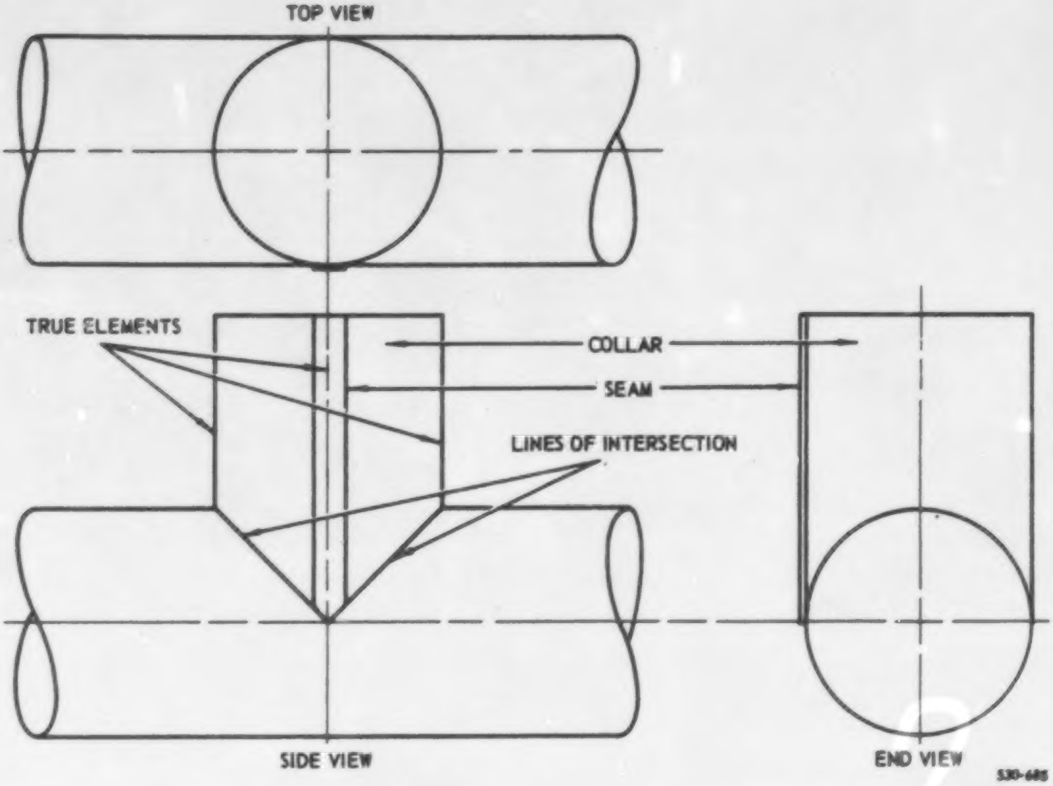


Figure 88. Parts of a T-joint.

elevation and plan views must be drawn. These two views, when constructed, will give you the true lengths of all miter and element lines. But some jobs will require additional views in order to complete the stretchout. In figure 88, you can see the two main parts of a T-joint—the collar, or branch, and main pipe. The lines where the main pipe and collar meet are called lines of intersection. These lines are also called miter lines. Notice that the miter lines meet in the center portion of the main pipe to form a vertex. There is no hard and fast rule for determining this location, but positioning it at the center gives a stronger and better looking joint. The element lines shown in the side view are on the outside of the collar and are drawn from the top of the pipe to the miter lines. Although stretchout patterns for T-joints are made in much the same manner as for elbows and Y-branches, let's examine each step.

18-28. Figure 89 illustrates the method of constructing miter lines in the elevation view and the projecting lines from the plan views. Both pipes shown have a diameter of 3 inches to simplify the layout explanation. Draw elevation view A by using a T-square and rule. Draw line AB 3 inches long. Draw lines AC and BD perpendicular to line AB. Draw line CD parallel to line AB. Draw the half plan view B directly below the elevation view, and divide half of the arc into three equal spaces. Number and project the dividing points to elevation view A by using the T-square and triangle to form lines 1 through 7. In this example, the intersecting point for the collar is at the center of the elevation view. At the center of line AC in the elevation view, draw the dotted line 1-7-1 so that it will extend 2 inches beyond line BD. Line EF is 3 inches long; set the compass for 1½ inches and strike an arc from the 2-inch mark on line 1-7-1. To both sides draw solid lines 4E and 10-F using a T-square. Draw line EF 2-inches to the right of line BD using the T-square and triangle.

18-29. Draw half plan view C and divide the arc into six equal parts and number as shown in figure 89. Project the points on the arc with a T-square until each point intersects a line. Notice where the horizontal element lines intersect the vertical element lines in the elevation view. Draw the V-shape miter lines by joining intersecting points 1, 2, 3, 4, 5, 6, and 7. Miter line

1-4 is 45° to line AB. Miter line 4-7 is also 45° to line AB.

18-30. To develop a pattern for a collar, shown in figure 89, draw a stretchout line equal in length to the circumference of the pipe. Divide the stretchout line into 12 equal spaces, and elevate the element lines. Transfer the element line lengths to the stretchout, and join the intersecting points as before. Notice the collar will be joined at the cheek.

18-31. To develop a stretchout pattern for the main pipe, the length of the stretchout line will be equal to the circumference of the main pipe (9.4248 inches), and the height will be 8 inches. Divide the stretchout into 12 equal parts, and elevate the element lines. Notice that the numbering is somewhat different in this stretchout. In this case, it is easier to start numbering in the center, since the joining point is line AC and the center is line BD. The cutout is on both sides of center. The length of the cutout lines can be projected easily with a T-square from the elevation view; however, these projection lines are not shown in figure 89. Points 1 through 7 in the elevation view are projected to form the cutout. When the intersecting points in the stretchout are connected, you have a pattern for the main pipe. Compare the numbering of the element lines in the stretchout with the numbering of the element lines in the elevation view.

18-32. This completes our discussion of the parallel line method of pattern development. We have shown you how patterns are developed for elbows, Y-branches, and T-joints. You should have noticed that each round, square, or rectangular duct developed by the parallel line method has not changed in diameter or cross section; therefore, the sides and elements lines in each pattern have remained parallel. In the following paragraphs we will show you how to use the radial line layout method to develop patterns for components, such as cones and pyramids, that *do not* have parallel sides.

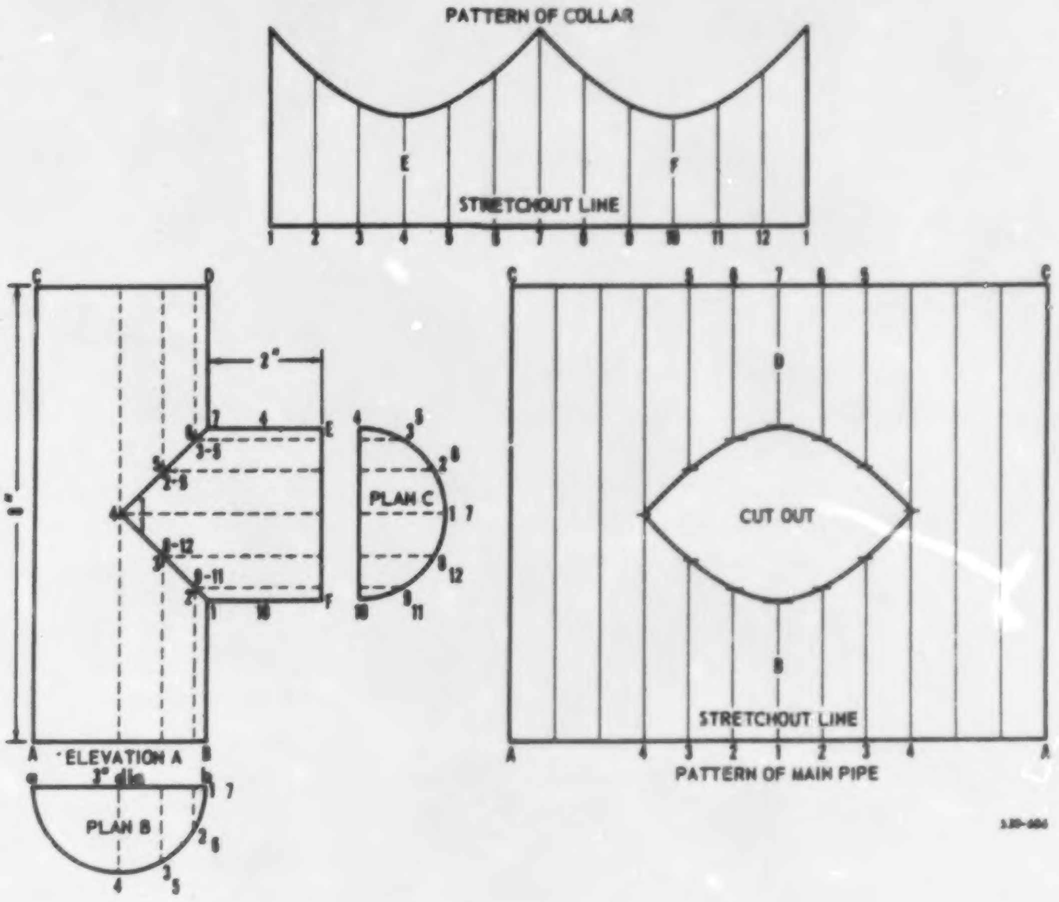


Figure 89. Developing patterns for a T-joint

18-33. **Radial Line Layout Method.** The radial line method of layout is used to develop patterns for sheet metal components that are cone or pyramid shaped. However, each cone or pyramid must have a centerline (vertical height) that is perpendicular to the base; in other words, a right cone or a right pyramid. While the characteristics of the radial line method of pattern development differ somewhat from those of parallel line development, you will notice that certain steps, such as drawing the elevation and plan views, are similar. Figures 90 and 91 will show you these basic similarities. For example, in each illustration the elevation view shows the height of the object, and the plan view determines the length of the stretchout line. These two views are drawn first. Draw the stretchout arc with a radius equal to the true height. Draw this arc long enough to allow each space in the plan view to be stepped off and lettered or numbered. Get the element lines from the elevation view and draw the stretchout to complete the pattern. You studied these operations in parallel line development.

18-34. All cone- and pyramid-shaped objects that are to be developed by the radial line method have certain characteristics: a circle for their base or at a base that can be inscribed in a circle, and sides that slant to a common vertex which is located directly over the center of the base. Figure 92 shows several examples of bases that can be inscribed in a circle.

18-35. To obtain the true height for a pattern, study the illustration shown in figure 93 and notice the vertical height, the slant height, and the true height. In this illustration, draw the elevation view (ABC) first, followed by the plan view which shows the shape of the pyramid base. Observe the plan view is inscribed within a circle. To get the true height, set the compass equal to the distance 0′ Y′, using 0 as a center, and make an arc on the extended line AC at point Y. Then draw the slanting line BY, which is the true height of the pyramid and will be the *true length* of the radius in the stretchout.

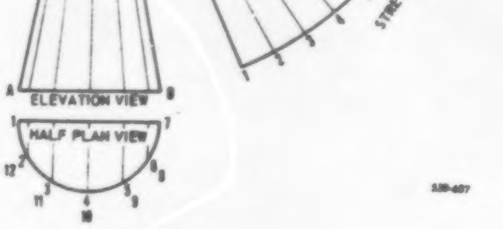


Figure 90. Radial line development for a cone.

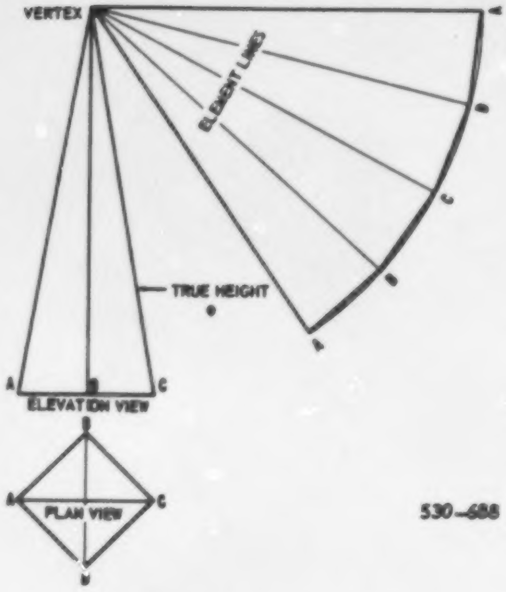


Figure 91. Radial line for a pyramid.

18-36. Figure 94 shows (view B) an example in which the position of the base in the plan view is arranged so that the slant height (AC) in the true elevation view will also be the true radius for the stretchout arc. *Do not* make the mistake of using the slant height (AB) as shown in the front elevation view (view A) for the true radius of the stretchout arc. When the pattern is cut and formed the height of the pyramid will be considerably less than desired.

18-37. In view B of figure 94 the elevation view appears larger because the slant line AC will be the true length for the radius in developing the pattern. The ultimate shape of the object depends greatly upon the arrangement of the elevation and plan views. This clearly shows that to construct the true height you must draw the base of the elevation parallel to a diagonal line which is the widest part of the plan view.

18-38. Although there are similarities between radial line development and parallel line development, you have just learned one of the differences. To determine the true height of a pyramid, it is necessary to draw the plan view before drawing the elevation view.

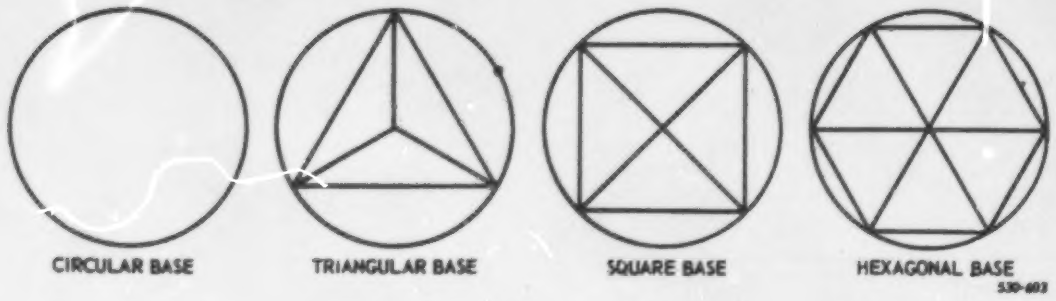


Figure 92. Bases that can be inscribed in a circle.

18-39. *Right pyramid.* The shape of the pattern for a right pyramid having six sides can be illustrated by holding its vertex at a definite point and rolling the pyramid as shown in view 1 of figure 95. This shows the outline of each face of the pyramid as imprinted upon the surface over which it is rolled; view 2 shows the stretchout of the same pattern.

18-40. To develop a pattern for a six-sided pyramid such as that shown in figure 95, first draw the plan view, which in this case is a hexagon. The dimensions of this hexagon are the same as those of the base of the pyramid. Each edge is numbered as shown in the illustration. From these numbered points, project vertical lines downward to intersect the base line of the elevation view. This establishes points 1 through 6. Point C is the vertex, which is determined by the vertical height of the given pyramid. From the points of intersection on the base line, element lines are drawn to the vertex. All lines from vertex C represent edges of the pyramid which are equal in length; however, they do not appear so in the elevation view because of the inclined surfaces. Therefore, only the outside lines give the true lengths for use as the radius of the arc in the stretchout. Next, draw the arc for the stretchout and points 1 through 6 are stepped off with spaces equal to the length of any side shown in the plan view. Number these points as shown in view 2. The points located along arc AB are each connected with straight lines and element lines drawn from each point to the vertex. This completes the pattern. Although the element lines you have just drawn are not absolutely necessary when forming the pyramid, they do clearly show where the folds will be made when the object is formed.

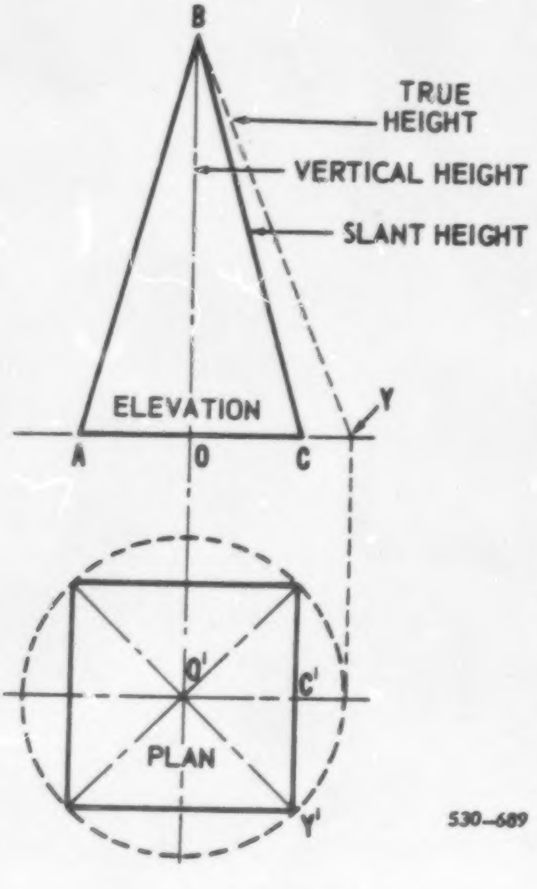


Figure 93. Height of a pyramid.

18-41. *Truncated pyramid.* A pyramid with the top cut off (truncated) parallel to the base is called a regular frustum of a pyramid. A pyramid with the top cut off at an angle to the base is called an irregular frustum, as shown in the elevation view of figure 96. The pattern for an irregular frustum of a pyramid is developed in a manner similar to that for an entire pyramid—with the exception of the element lines, which are no longer the same length. To construct this pattern, draw the plan view and elevation view as previously described; this provides the shape and dimensions of the pyramid. Observe in the elevation view that lines have been constructed to locate the vertex of the pyramid; this is an essential part of the pattern. The plan view shows

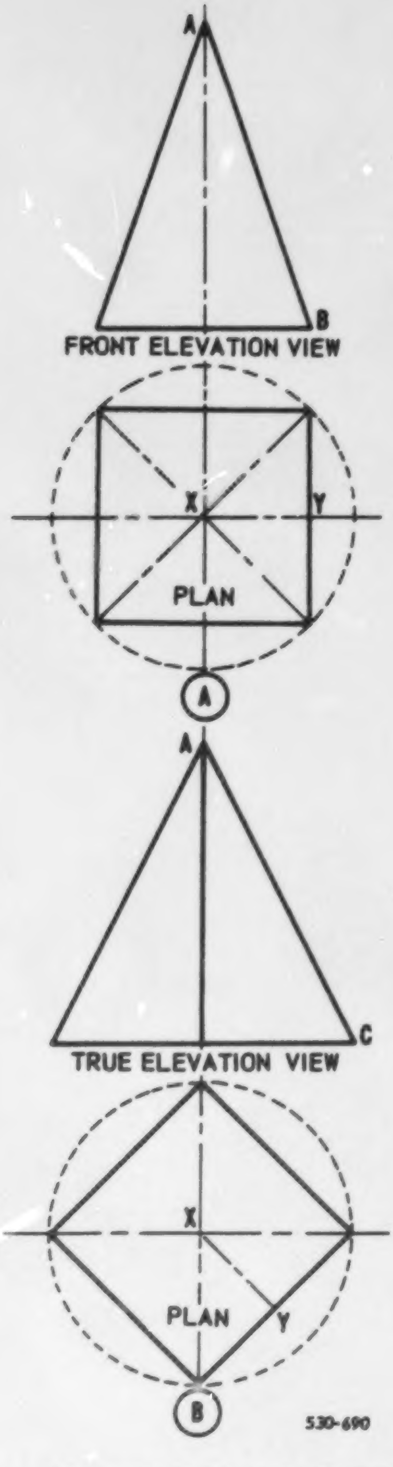


Figure 94. Arranging a plan view of a pyramid.

the base outline of the pyramid from which the side widths may be obtained. Draw the stretchout the same as for an entire pyramid, except for the length of the element lines. You are now at the step where the method of obtaining the true length of the element lines is different because of the truncation.

18-42. Suppose the pattern begins with the shortest element (line 0′-1). This element line, as seen in the elevation view of figure 96, is of true length and can be transferred to the stretchout. Element lines 2, 6, 3, and 5 do not show their true lengths, because they are inclined to the plane of projection. This means that to find their true lengths, you must imagine the pyramid's being rotated until the edges concerned come into the position of element line 1, where the true lengths can be seen. To accomplish this on the elevation drawing, draw a horizontal projection from the upper end of element lines 2 and 6 until it crosses the extension of element line 1. The true length of element lines 2 and 6 is the distance from this point of intersection to the base line of the elevation view. Find the true length of element lines 3 and 5 in the same manner. Element line 4 is shown in its true length and need not be projected. These true lengths along line 0-1 are transferred to the stretchout to form the pattern. The points of intersection are connected with a straight line, resulting in a completed pattern for a truncated pyramid.

18-43. *Right cone.* Developing a pattern for a cone is somewhat simpler than for a pyramid, because the true height and slant height are the same. The radial line method of pattern development is also used for whole cones or truncated cones with the tops cut off, as shown in figure 97. A cone with the top cut off (truncated) parallel with the base is called a regular frustum. One with the top cut off on any angle with the base is called an irregular frustum. Generally, the pattern for a cone is fan shaped, as shown in figure 98; when the object is unrolled, the stretchout pivots (radiates) around the vertex.

18-44. To develop a pattern for a *regular frustum* of a cone, you must draw the elevation and half plan views. In figure 98, the vertex is lettered A and the base line BC. At any point on the cone, and parallel to line BC, construct a line that cuts off the top portion of the cone and letter line DE. Draw the half plan view beneath the base of the frustum and divide into equal sections, as previously done in parallel line development. From the numbered points on the half plan view, erect perpendicular lines to the base of line BC. From the points at which these lines intersect BC, draw lines to the vertex A. These element lines that you have just drawn

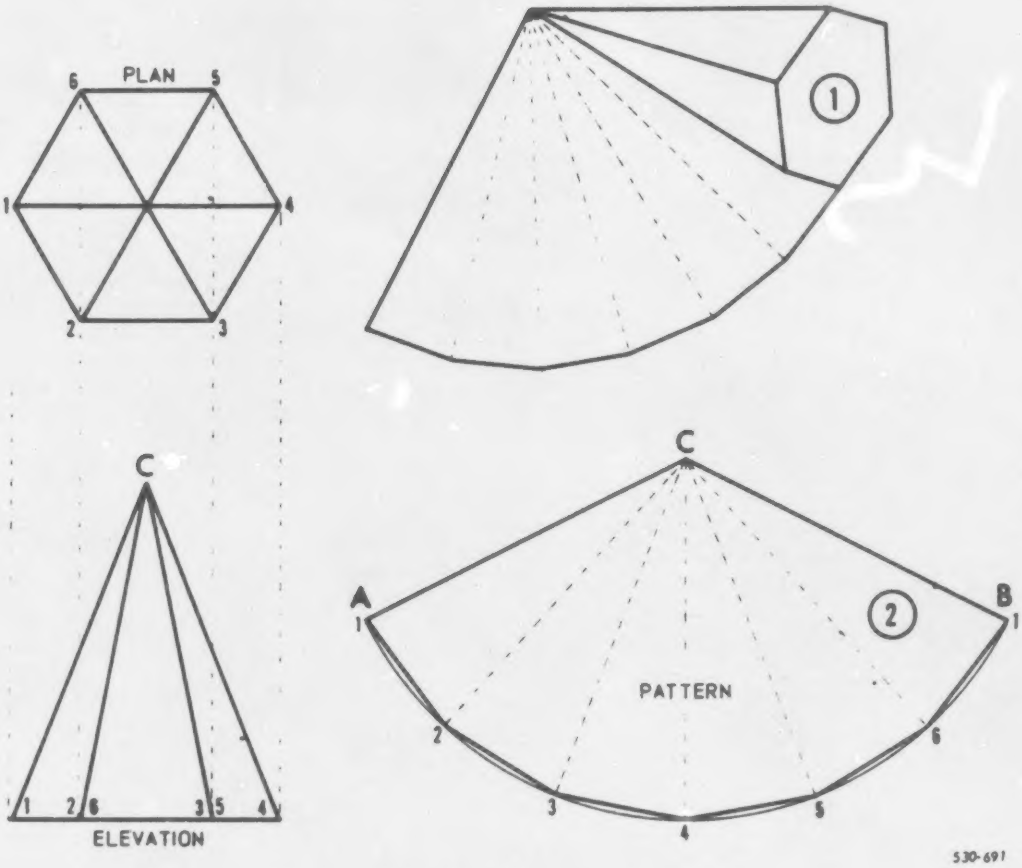


Figure 95. A right pyramid.

are not absolutely necessary for the construction of the stretchout pattern; however, they do show that the element lines in the elevation view converge at the vertex. Since line BC represents the widest part of the plan view, lines AC and AB are of true length (true height). Draw the stretchout arc with vertex A as the center and the radius equal to the length of line AC. From the same center, draw another arc with a radius equal to line AE. Element lines need not be drawn, since there are no folds or edges as with pyramids. The area inclosed between the arcs and both number 1 lines is the pattern for the frustum of a cone. After you add allowances for seaming and edging, the stretchout will be completed.

18-45. If an *irregular frustum* of a cone such as that shown in figure 99 is to be developed, the truncation line DE is drawn in the elevation view. This line represents the top edge of the object. Divide the circumference of the half plan view into equal sections as previously done in parallel line development; in this case, it will be from 1 to 12 to 1. From each of these points, erect a perpendicular line to the base of the frustum. Then from each point of intersection with the base, draw radial lines to the vertex. From each point where the radial lines intersect the truncation line on the elevation, project horizontal lines to line AC and number 1 through 12, as shown. The distance from the vertex along line AC to any of these points will give you the true length of the corresponding radial line.

18-46. To construct the pattern, draw the stretchout arc with a radius equal to the distance from A to C, as shown in figure 99. Now divide the stretchout into 12 equal spaces and number to correspond with those in the half plan view. From the points of intersection with the stretchout arc, draw element lines to vertex A. It is necessary to construct these lines because they are essential in developing the pattern. Next, with a compass and using the vertex as a center, measure the distance between points A and 1 along line AC. Transfer this measurement to the stretchout arc; again using the vertex as center, swing an arc to intersect the corresponding element line

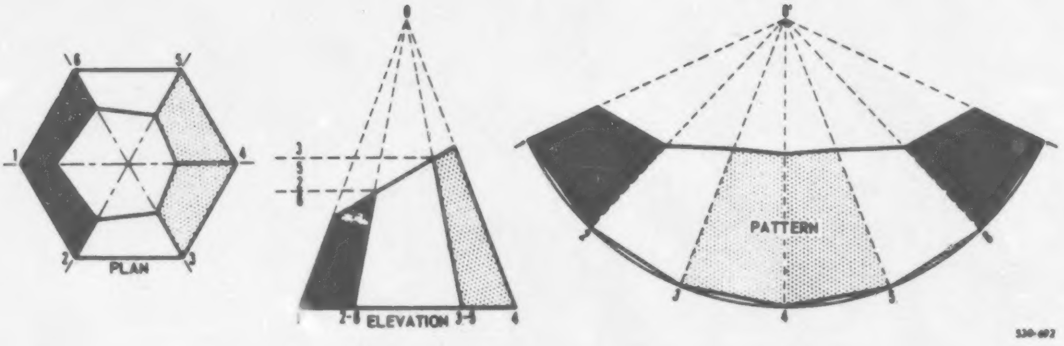


Figure 96. Truncated pyramid pattern development.

(1) in the stretchout arc. Repeat this procedure for each of the numbered horizontal lines in the elevation view. Then with an irregular (French) curve, connect these points. This curved line determines the top edge of the pattern, and the stretchout arc determines the lower edge.

18-47. We are going to describe a job situation which you may encounter. Suppose you are to replace a piece of half-round gutter with a 4-inch downspout outlet which is tapered to 2 inches. In the pictorial view of figure 10, you can see that a miter is needed so the downspout connector will fit the contour of the gutter. To lay out the downspout connection, you will have to determine which layout method to use. (Since the downspout connector is tapered, the radial line method will be used.) Begin the pattern by drawing an end view of the gutter 6 inches in diameter, as shown in the illustration. Next, draw the elevation view and half plan view. After determining and numbering the dividing points on the half plan view and drawing element lines in the elevation view, project and number the horizontal lines. After the stretchout arcs are drawn and divided into 12 equal spaces, extend the element lines to the vertex. Determine the length of the element lines and transfer them to the pattern. Notice how this pattern, if rolled up so that both number 1 element lines meet, will fit the contour of the gutter.

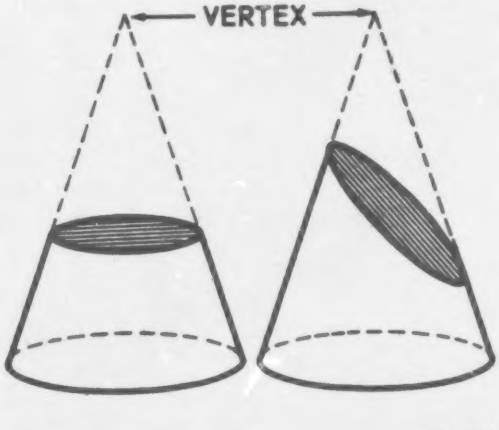


Figure 97. Truncated cone.

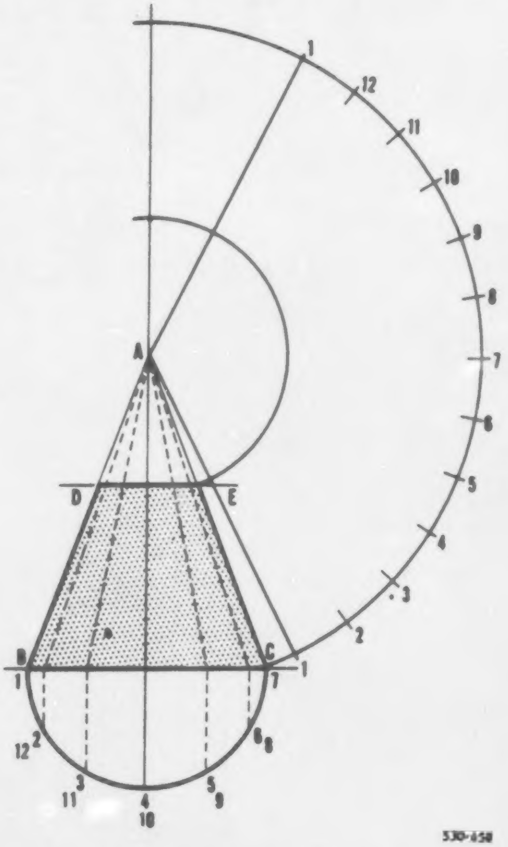
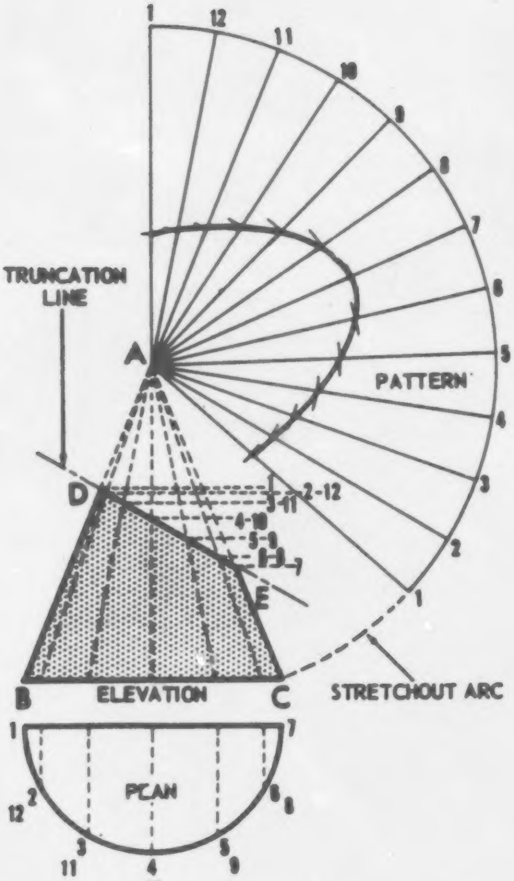


Figure 98. Regular frustum pattern development.

76



530-694

Figure 99. Irregular frustum pattern development.

18-48. This completes our discussion of the radial line method of pattern development. We have shown you how patterns are developed for tapered components such as pyramids and cones. In the following paragraphs, we will discuss the triangulation method of pattern development for components that do not have a common center or parallel sides.

18-49. **Triangulation Layout Method.** You are probably beginning to realize that regardless of how complicated the component may be, the pattern can be developed by application of the principles in this chapter (parallel line, radial line, or triangulation methods). There are many irregular shapes such as transitions and offsets in sheet metalwork which have patterns that cannot be developed by the methods already explained. Examples of transitions are shown in figure 101. Notice that lines drawn on these irregular shapes do not run parallel with each other or meet at a common point. Instead, the surface is divided into a series of triangles which slope in many directions. Finding the true lengths of these sloping triangles makes it possible to develop the patterns.

18-50. In triangulation, the surfaces of the elevation and plan views are divided into a convenient number of triangles, the sides of which form the element lines. When you look at these element lines from the plan view and elevation view, they appear shortened. To make this a little clearer, suppose you take a pencil about 6 inches long and hold it at arm's length, perpendicular to the line of sight, as shown in figure 102. Now, as you tilt the top end of the pencil away from you, notice how its length appears to shorten. If you measure the pencil in this position, it will still be 6 inches long, although it appears shorter.

18-51. Before the sloping lines of transitions can be transferred to a pattern, their true lengths must be found by making a true length chart. In some cases, it is necessary to show the element lines in two views as a basis for finding these true lengths. The elevation view shows the vertical height of the element lines, and the plan view shows the horizontal distance covered by the same lines. You can see in figure 103 how these two distances are laid off as the sides of a right triangle—the hypotenuse of which shows the true length of the element line.

18-52. *Oblique cone.* Now let's apply the triangulation principles in the development of an oblique cone, such as the one shown in figure 104. First, construct the plan view and divide the circumference into an equal number of parts as was done in parallel with radial line developments. From these points on the circumference, draw straight lines to vertex A′. Observe how these lines appear to be the element lines. Actually, they are the beginning of the right triangles which are about to be constructed. Next, draw the elevation view to represent the side and height of the cone.

18-53. From the numbered points in the plan view, project vertical lines upward until they intersect the base of the cone in the elevation view. From these points of intersection, draw straight lines to vertex A as shown. In this manner, element lines are established for the elevation view. These element lines represent the relation between the elements of the plan and elevation view and *should not* be taken as true length lines.

18-54. The next step in laying out a triangulation pattern is to determine the true lengths of all element lines in the elevation view. To find these true lengths, draw a true length chart (fig. 104) with right triangle BCD constructed so that line BC is the vertical height of all elements. Set a compass equal to the length of line A′-1 in the plan view. With C as a center in the right

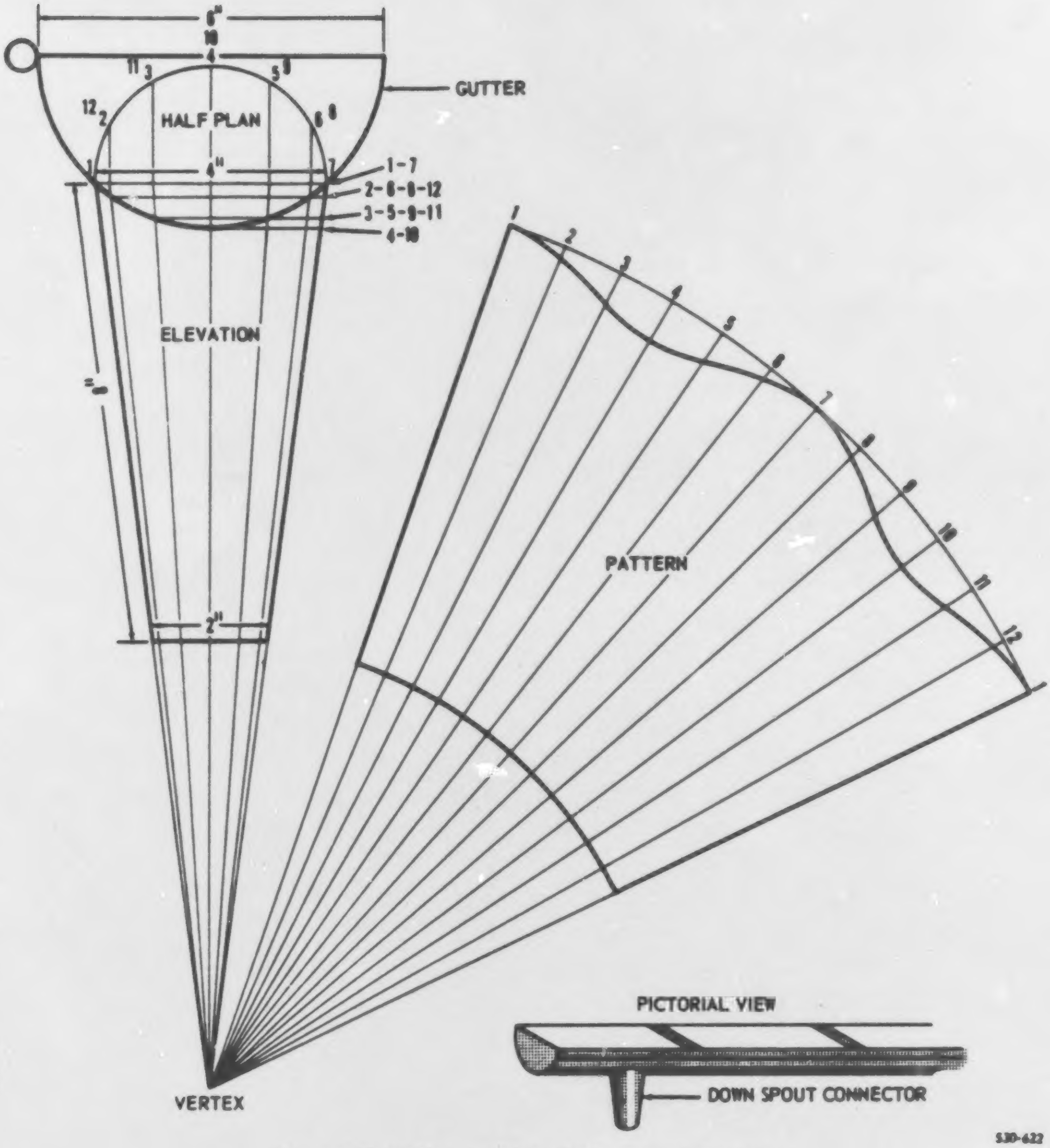

6"
10
4
11 3
5 9
GUTTER
12 2
HALF PLAN
6 8
1
4"
7
1-7
2-6-8-12
3-5-9-11
4-10
8"
ELEVATION
2"
VERTEX
1
2
3
4
5
6
7
8
9
10
11
12
1
PATTERN
PICTORIAL VIEW
DOWN SPOUT CONNECTOR
530-622

Figure 100. Making a pattern for a gutter downspout.

triangle, scribe an arc so that it intersects line CD at 1. Next, set the compass equal to the length of A′-2 in the plan view, and transfer the measurement to the right triangle in the same manner for A′-1. Continue this until all numbers in the plan view are represented on line CD and numbered as shown. From these numbered points on line CD, draw straight lines to vertex B. These lines each represent the hypotenuse of a right triangle and, therefore, form the true lengths of the elements to which they correspond. After setting up the true length chart, draw the pattern.

18-55. In drawing the pattern for an oblique cone, you must establish a reference point similar to the ones used in the previous developments. A common point is selected to work from, such as X in figure 105. From point X, draw a straight line equal in length to the short side of the cone (line B-1 in figure 104). This line is essential to the pattern because it is the reference line and also serves as one edge of the pattern. (At this point in triangulation, we suggest that you use two compasses to transfer measurements. Set one compass, for repeated use, to the distance between element points as shown in plan

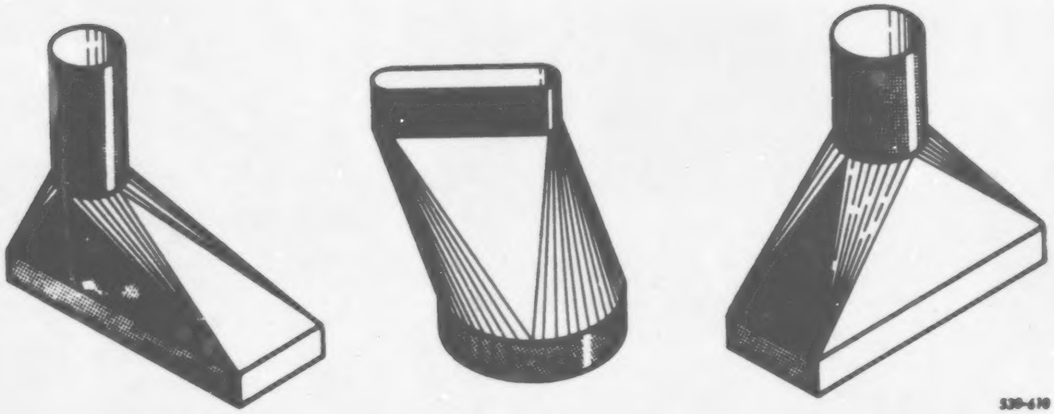


Figure 101. Transitions.

view of figure 104. The other compass is used to transfer the various true lengths of the element lines from the true length chart. The reason we suggest this method of transferring dimensions is it will assure an accurate distance between the element lines at all times, and minimize readjustment of the compass.)

18-56. Having already established line X-1, as shown in figure 105, the next step is to establish points 2 through 12 to 1. The distance between each of these points is made with the compass which is set for repeated use. Starting with point 1 as a center, strike a small arc to the right, then use the other compass to transfer the length of line B-2 from the true length chart (fig. 104) to determine the length of line X-2 in the pattern (fig. 105). With point 2 established, draw an element line from vertex X to point 2. This process is repeated to establish the remaining element lines X-3, X-4, X-5, etc. With these points established, use an irregular (French) curve to connect points 1 through 12 to 1, which becomes the stretchout pattern for an oblique cone.

18-57. *Offset cone.* The offset cone is similar in shape and general appearance to the oblique cone. The method of making a pattern involves additional steps. Notice in figure 106 there are two circumferences for the frustum that do not share the same center. Each circumference is divided into the same number of equal parts. Connecting the points of each circumference forms the base of right triangles, such as triangle 2-3-4, which is necessary for the construction of the pattern. Two true length charts (one with solid lines and one with broken lines) are used to avoid

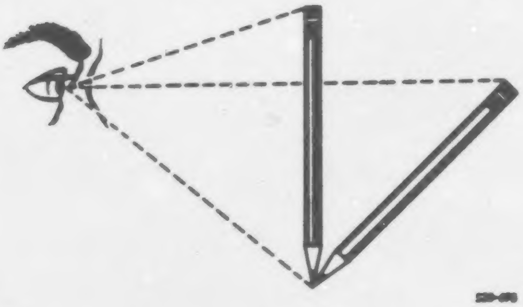


Figure 102. Line of sight.

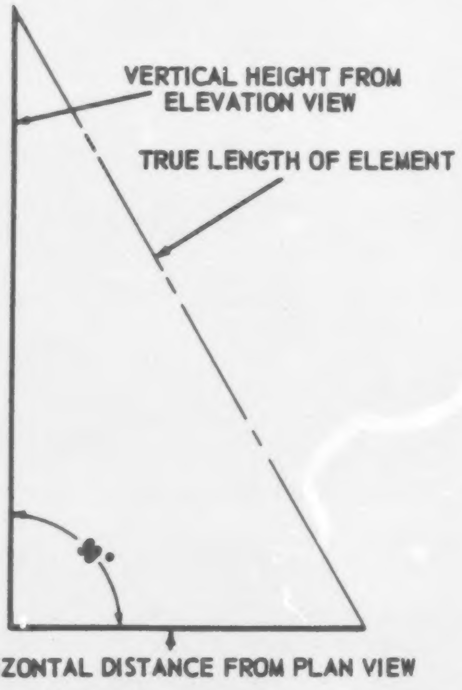


Figure 103. True length line.

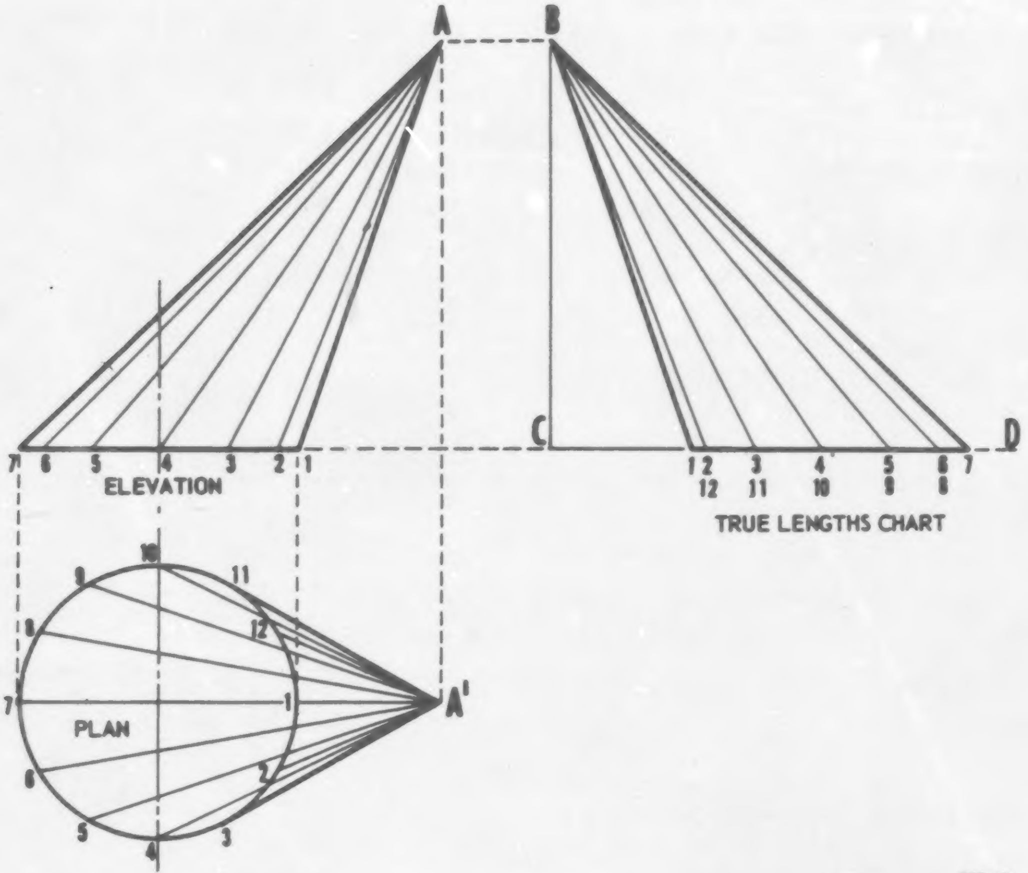

A
B
C
D
7
6
5
4
3
2
1
ELEVATION
1 2
12
3
11
4
10
5
9
6
8
7
TRUE LENGTHS CHART
10
9
11
8
12
7
1
PLAN
A'
6
2
5
3
4
530-696

Figure 104. Oblique cone.

confusion when transferring true lengths to the pattern. Other than this, the method of developing the pattern for an offset cone is similar to that for developing a pattern for an oblique cone.

18-58. Before constructing the pattern for an offset cone frustum, you must draw the plan view directly over the center of the elevation view, as shown in figure 106. You must draw these two views to the exact height and shape of the object. Since this particular frustum is symmetrical in shape (two equal halves), only half of the required element lines need to be drawn in the plan view. After you draw the plan and elevation views, divide the circumference in the half plan view into the same number of equal parts number these points so that the even numbers are all on one perimeter and the odd numbers on the other. From the numbered points in the plan view (starting from point 1), draw a solid line from 1 to 2, then a broken line from 2 to the odd number 3. Continue this process until the plan view resembles the one shown in figure 106.

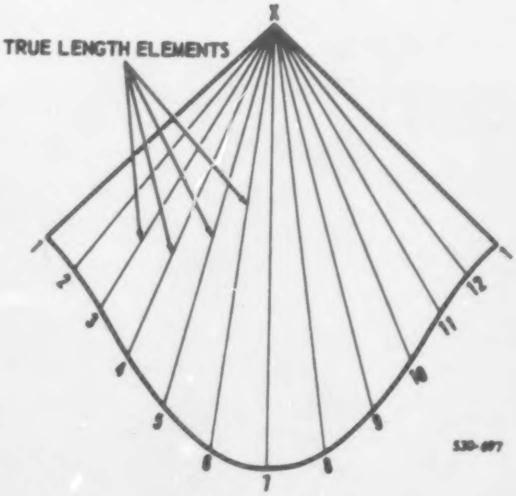

X
TRUE LENGTH ELEMENTS
1
2
3
4
5
6
7
8
9
10
11
12
1
530-697

Figure 105. Oblique cone pattern.

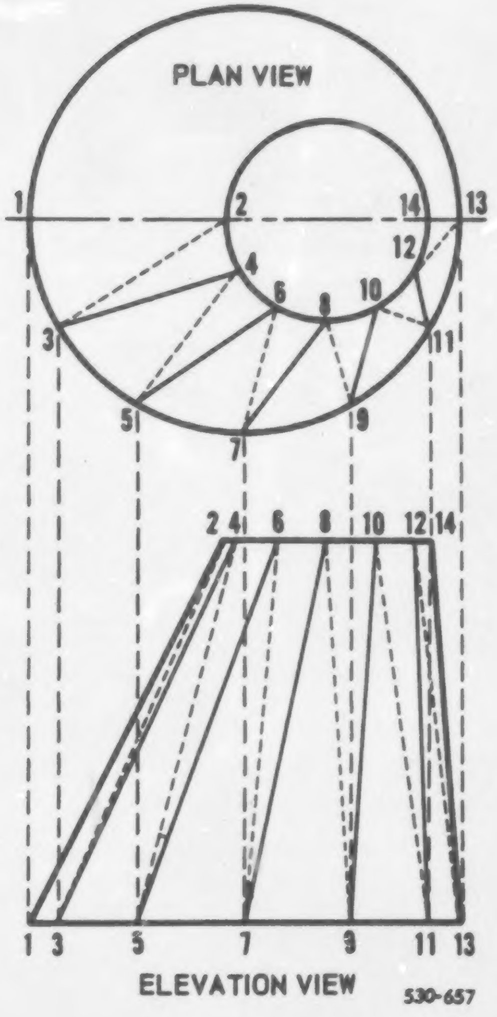


Figure 106. Offset cone.

18-59. In the elevation view, the element lines are projected down from the plan view; however, this is not a required step and is done merely to show you the position of the element lines on the outside of the cone. *Do not* assume that these element lines are of true length, because they are not. The only true length lines in the elevation view are lines 1-2 and 13-14. To determine the true length of the other element lines it is necessary to draw *two* true length charts, as shown in figure 107. Use chart A for the solid lines and chart B for the broken lines. Follow this process, as pointed out before, to obtain the hypotenuse of each right triangle, which represents the true length of the element lines.

18-60. To construct the pattern for an offset cone, as shown in figure 108, the half-pattern stretchout is begun by drawing line 1-2 (its true length), which is obtained from view A of the true length chart in figure 107. This is the reference line for the pattern, and all future points or lines must be built around it. The distances between the *odd*-numbered points (1 through 13) on the base line of the pattern are equal and identical to the distances between the same numbers in the plan view. The distances between the *even*-numbered points (2 through 14) of the pattern are equal and identical to the distances between the same numbers in the plan view. The element lines of the pattern are *not* equal in length but are identical to the lengths of the corresponding numbered lines in the true length charts. To complete the pattern, except for seam allowances, connect all points of intersection with smooth curved lines.

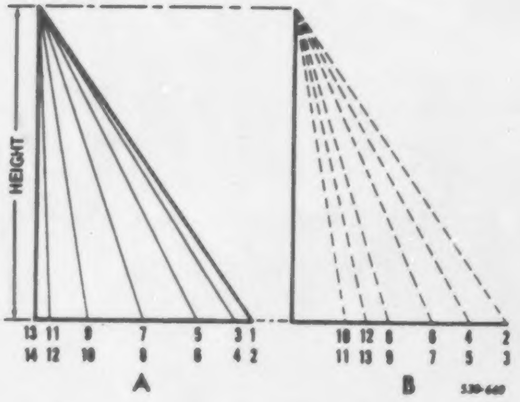


Figure 107. True length chart.

18-61. *Square-to-round symmetrical transition.* A transition is a sheet metal component designed to connect pipes or ducts of different shapes. Figure 109 is a pictorial view of a rectangular-to-round transition piece, and figure 110 shows the development of a square-to-round pattern. Both polygons are symmetrical; the pattern develop-

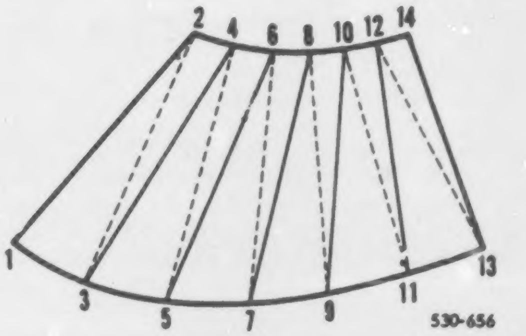


Figure 108. Offset cone pattern.

ment procedures are the same for both. In figure 109, the transition is made up of one isosceles triangle (ABC—with two equal sides) and two smaller right triangles where the sections join. In addition, eight parts with curved surfaces such as BCD are shown. Each group of curved surfaces forms one-fourth of the round opening and their vertexes meet in corners A, C, E, and F (F not shown).

18-62. Only a half pattern of the stretchout shown in figure 110 is needed because the transition piece is symmetrical in shape. You will have to cut two pieces to this pattern in order to complete the transition. Figure 110 shows the various steps necessary in the development of this pattern. First, draw the plan view as shown, keeping the exact diameter and diagonal of the round and square connectors. In other words, ABCD represents the square end and the circle represents the round end. Divide the circle into equal parts and number 1 to 7 to 12. From the numbered points on the circle, draw straight lines to vertexes A, B, C, and D to form right triangles. Next, draw the elevation view to determine the distance between the sections being joined.

18-63. From the numbered points on the plan view of figure 110 project lines parallel to the centerline so that they intersect the top of the elevation view. Number these points of intersection to correspond to the numbers in the plan view. When element lines are drawn from the numbered points to the corners of the base, triangles are formed. These are not true length element lines. To determine the true lengths of these element lines, you must set up a true length chart, as shown in figure 110, by drawing a right angle with a vertical height equal to H. Beginning with element lines A-1 in the plan view and using a compass, transfer lines A-1, A-12, A-11, A-10, and G-10 to the base line of the true length chart and number respectively. From the center of the plan view, you can see that the transition has four identical parts with several element lines of the same length. This is why the true length chart shows multiple numbers for each true length line. From the numbered points on the base line, draw straight lines to form a vertex. These straight lines are the true lengths of the element lines.

18-64. To start the half-pattern stretchout for the transition shown in figure 110, draw a horizontal line which is equal in length to AD in the plan view. Note the square end of the transition in the plan view is shown in its true length; therefore, no chart is necessary to determine the length of line AD. Set the compass to the true length of element line A-1, and using A and D in the half pattern as centers, swing two arcs so that they intersect, thereby forming an isosceles triangle. Number the point of intersection 1 and 7. Next, set the compass equal to the distance between points 1 and 2 in the plan view and transfer to each side of point 1-7 in the half pattern. (For greater accuracy, this measurement is often made by drawing a stretchout or straight line of the round end of the transition. This straight line, which is equal in length to the circumference of the round end, is then divided into equal spaces. The round end shown in the plan view of figure 110 has 12 spaces; therefore, a straight line for this example would be divided into 12 equal spaces. This method is more accurate, because the straight-line distance between two points on an arc is actually the length of a chord between the points rather than the length of the arc between the two points.)

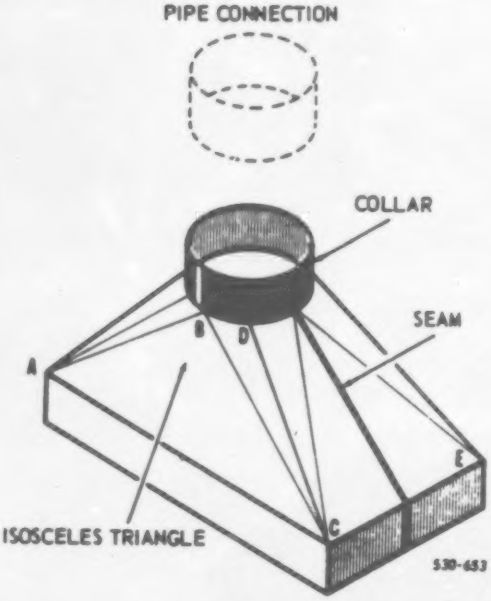


Figure 109. Transition.

18-65. The compass which is set to the distance between points 1 and 2 in the plan view is used repeatedly to establish the distance between the remaining points to the left and right of point 1-7 on the half pattern. The arcs which have been drawn to each side of point 1-7 (half pattern) are now to be intersected by arcs swung from points A and D. The radii of these arcs are taken from true length chart, line A-12 (D-2). Establish the remaining points to the left and right of the isosceles triangle vertex by repeating these steps using the appropriate true length lines. After numbering each point and drawing the element lines, the final steps are to

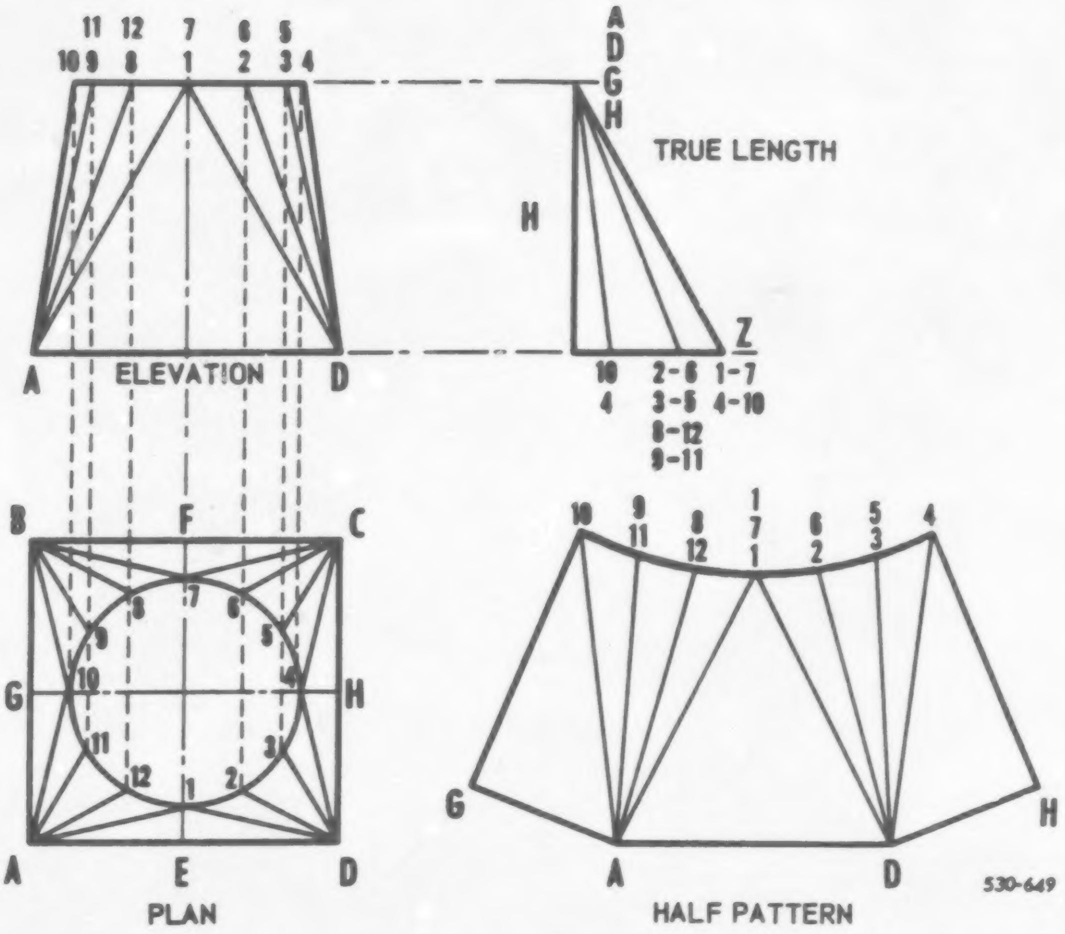


Figure 110. Developing a square-to-round transition pattern.

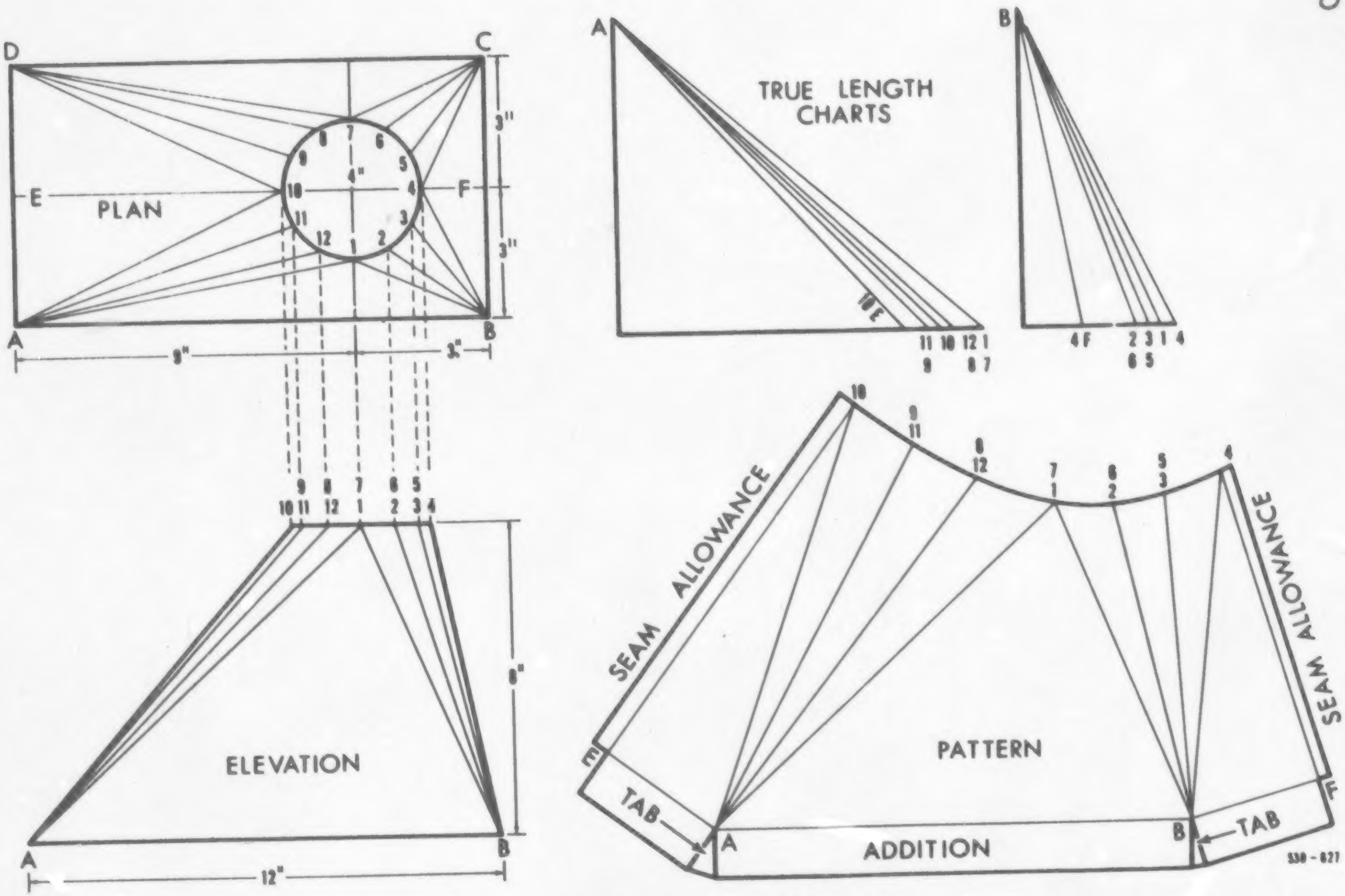
locate points G and H and draw lines A-G, G-10, D-H, and H-4. By connecting all points of intersection with straight or curved lines, you complete the pattern. This final step forms the two right triangles at the extreme ends of the half pattern.

18-66. You have seen why a transition that is symmetrical requires only a half pattern. However, a transition with a *double offset* will require separate half patterns, since all four sides are different.

18-67. *Offset rectangle-to-round transition.* A pattern for an offset rectangle-to-round transition is developed in much the same way as a square-to-round transition, and a half pattern will be sufficient if the offset is only to one side of center. The rectangle-to-round transition with the round section off center has two equal sides on either side of the centerline, as illustrated by line EF in the plan view of figure 111.

18-68. Draw the plan view and the elevation view with the round section off center. Draw the elevation view to the desired height (8 inches in this case). The two true length charts represent the element lines for each quarter part of the half pattern and are lettered A and B in figure 111. The true lengths of the element lines are found by using the same methods that are used for square-to-round transitions. The half pattern is developed using the measurements of the rectangular base, circumference spacing, and true length element lines.

18-69. Remember in pattern development the numbering of element lines begins where the component is to be joined. For patterns made by the triangulation method, the numbering starts at the center of the pattern. This completes our discussion of layout methods. You have studied how the parallel line method, radial line method, and triangulation method are used to develop patterns for sheet metal components. To simplify these discussions, we have not considered


PLAN
D
C
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B
3"
3"
9"
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4"
1
2
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4
5
6
7
8
9
10
11
12
ELEVATION
10 11 12 1 2 3 4
9 8 7 6 5
8"
12"
TRUE LENGTH CHARTS
A
10 E
11 10 12 1
9 8 7
B
4 F
2 3 1 4
6 5
PATTERN
SEAM ALLOWANCE
SEAM ALLOWANCE
TAB
TAB
ADDITION
E
F
330-027

Figure 111. Developing a rectangular-to-round transition pattern.

seam allowances and additions, although in actual practice they are included in the pattern development. In the following paragraphs, we will discuss seam allowances and additions which are made and described on the pattern.

18-70. **Seam Allowances and Additions.** In figure 111, you can see an example of seam allowances and additions to a pattern for a transition. Sheet metal patterns such as the two halves of the transition are assembled with seams. (Later in this course, you will learn to make and use several types of seams, such as lap seams and various types of lock seams.) Any one of these requires additional length or width to a pattern. Patterns developed by the parallel line, radial line, or triangulation method do not include allowances for seams; therefore, you must determine how much length or width is to be added. For example, if the transition shown in figure 111 is to be assembled with ¼-inch grooved seams, the pattern must allow for a ⅜-inch extension along line F-4 and ⅜-inch extension along line E-10. These seam allowances must be determined and added to the paper and metal patterns before they are cut out.

18-71. Figure 111 also shows *additions* to a pattern. This additional length may be needed for several reasons. For example, if the pattern is for a transition such as that shown in figure 109, the additions to each end are probably 2 or 3 inches. However, they can be more or less, depending on how the transition is to be used. The rectangle-to-round transition has additions at both ends which permit the duct to continue in the same direction, although the shape has changed from rectangular to round. Another reason for an addition is illustrated in figure 109, where the round addition is necessary to fit into the pipe connection. Still another use for additions is to extend the length of a component a few inches to fill a gap in a duct. If the rectangular end is to be connected to a rectangular-shaped duct, a seam allowance must also be added to the addition.

18-72. Suppose you need to add 2 inches to the pattern shown in figure 111 at lines AB, AE, and BF. Begin by squaring down from line AB 2 inches at points A and D and striking a mark, repeating the same at points E and F. The marks are joined with straight parallel lines.

18-73. Notice the additions shown in figure 111 have tabs at A and B. The two tab lines at points A and B are perpendicular to the base lines of the triangles shown in the pattern. Only one of the tab lines at points A and B is cut, so the corners can be joined when the transition is assembled. The tabs are secured by spot welding or riveting when the pattern is assembled.

18-74. In figure 112, the rectangular duct pattern will need an allowance for connecting the ends (*a*). If the duct is joined without making an allowance for seams, it will have two short sides. Suppose this duct is to be joined with a Pittsburgh lock seam. The seam allowance is determined by the type of seam to be used. (Later in this course, you will learn how seams are made and the allowances needed for each type of seam. In Volume 1, you are to study how seam allowances are included in the patterns.) To make the Pittsburgh lock seam, allowances are made on each side of the duct. On one side, 15/16 inch or 1 inch is needed, whichever the machine in your shop requires. On the opposite side of the pattern, ¼ inch is needed to complete the lock seam allowance. The length of the duct will also need allowances, since it will be joined to another duct on one end or both ends. Again the allowance will be determined by the connec-

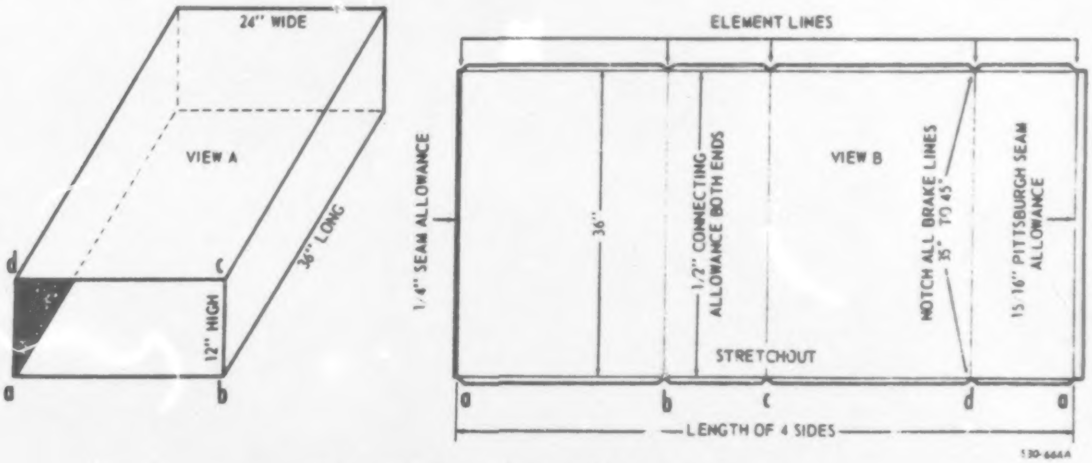

Figure 112. Seam allowance for a rectangular duct

tion. If you are using an S-shaped hook to join the duct on both ends, you must allow ½ inch on either end of the length, since it requires ½-inch allowance. All element lines to be folded should be notched as shown in figure 112 so that the connection can be made more easily.

18-75. Layout tools useful for drawing seam allowances and additions on paper patterns include the compass, T-square, irregular (French) curve, steel rule, and triangles. The layout tools used to make seam allowances and additions on metal patterns include the framing square, combination set, dividers, and scribe. The procedures involved in making seam allowance and additions to patterns include using these tools to measure and make parallel lines.

19. Transferring Patterns to Metal

19-1. In the previous discussions about layout, you probably wondered why it was suggested to first draw the pattern on paper. Two reasons for using paper are development lines can be seen much more easily on paper during the layout process and materials can be saved when several different patterns are arranged on the sheet metal close to each other. In a previous section, we referred to making templates (metal patterns) of components that are frequently made in the shop. When several of the same components are being made, metal patterns or templates are used, since paper patterns become frayed and worn, causing defects when marking lines and points. When transferring a pattern to metal, you are simply using the outside lines and points to mark the metal so that it can be formed into the shape of the component. All points and lines should be marked to eliminate mistakes when you are forming the component.

19-2. Transferring *paper patterns* to metal is done by duplicating the points at the ends of element lines on the metal. A pencil with a sharp point should be used to carefully mark the outside lines. Weights can be placed on the pattern to prevent slipping during the transfer. The points and lines are then prick-punched on the metal for clarification. (A prick punch is a sharp-pointed punch.)

19-3. Transferring *metal patterns* is just like transferring paper patterns, except that different tools are used. A scribe is used to mark the edges and lines. The prick punch is used to mark points at the end of element lines, just as is done for paper pattern transfer. The metal pattern or template can be held in place with weights or a clamping device.

19-4. Transferring a pattern for a *rectangular duct* is fairly easy. For example, the pattern in figure 118 is transferred to metal by duplicating its shape and using a prick punch to locate the ends of the element lines. Lines *b*, *c*, and *d* are the brake lines when forming the duct.

19-5. Transferring the pattern for a *cone-shaped component* with a miter, such as shown in figure 83, is done by simply duplicating the shape of the mitered pattern on the sheet metal.

19-6. Transferring *elbow patterns,* such as those shown in figure 86, requires a little different method. This is a single pattern that is sufficient to make five pieces for the elbow. The working line on this pattern is very important when you are transferring the pattern to metal. During the following explanation of the transfer, you will see why marking the pattern for identification is necessary. A five-piece elbow requires five gores. Marking gores I and V require half the pattern (A or B), which is divided at the working line. Gores II, III, and IV are made by using the whole pattern (A and B). Thus you can see that transferring elbow patterns to metal is similar to transferring other patterns, except that you must remember to use half patterns for the end gores.

19-7. If you need to make a 45° elbow, the same elbow pattern can be used by transferring only 2 half gores and 1 full gore. Notice in the plan view of figure 86 that each of the whole gores is divided by broken lines to show whole and half gores.

19-8. Transferring patterns for a *round Y-branch,* as shown in figure 87, is similar to the process for other patterns. This layout has only three patterns. The pattern for piece III is transposed only one time, whereas patterns for pieces II and IV and I and V are transposed twice.

19-9. Transferring patterns for a *T-joint,* such as that shown in figure 89, is done by marking on the outside edges, except for the cutout in the pattern of the main pipe. The cutout is marked on the inside so that the line can be cut out before forming.

19-10. When transferring a pattern for a *pyramid,* such as that shown in figure 95, the lines are made on the outside edge and at the intersecting points. The intersecting points are the brake lines for forming the pattern into shape.

19-11. When transferring the pattern for a *round offset,* such as that shown in figure 108, you will need two half patterns, since it was laid out in a half pattern. If you want to make only one seam instead of two with this half pattern, it is necessary to mark one half of the pattern, roll it end-to-end aligning lines 1-2, and continue marking the other half.

19-12. The procedures for transferring patterns for *square-to-round components,* such as those shown in figure 110, are much the same as for other patterns. The outside of the pattern is marked, and ends of the element lines are prick-punched so that they may be seen when you are forming the component.

19-13. In this chapter, you have learned how patterns are developed from working drawings. This included the parallel line, radial line, and triangulation methods of pattern development. You studied about seam allowances, additions, and how patterns are transferred to metal.

CHAPTER 6

Sheet Metals

AS YOU PASSED through the food serving line in the dining hall, did you ever wonder why the metal of the serving line was shiny or why the surface remained shiny? Or maybe you have noticed several buildings with gutters made of different metals and wondered why they are different. You may have asked yourself how the metal was formed into shapes of gutters without breaking. The information in this chapter will help to answer these questions and others that you may have.

2. In the preceding chapter you learned pattern development, and in this chapter you will learn about sheet metals. Selecting the metal is another step forward in preparing you to fabricate sheet metal components. To select the metals, you will have to know something about them. Therefore, we will discuss properties of metals, such as hardness, toughness, and elasticity, as well as changing properties. To select sheet metals, you will have to know the size of sheets, the finish, the composition, and the forming qualities, which we will discuss.

3. Since you are assigned to a metalworking career field, you need to know metals—their properties, composition, and forming qualities. Also, you need to know the differences in metals so that you can select the correct one for the job requirement. You need to know metals that are corrosion resistant, since selecting the wrong material could result in your having to do the job over. You need to know the forming qualities of metals, since most jobs require that the metal be formed.

4. You can use your knowledge of metals to select a metal to fabricate such items as roof flashing, heating and air-conditioning ducts, as well as dining hall equipment. Knowing the thickness of metals can help you select one suitable for the job and the working capacity of the machinery in the shop. You can use knowledge of metals that are light in weight when a job requires a light metal but one that is strong enough to support the job.

20. Properties of Metals

20-1. To select a metal for a job, you will have to know something about properties of metals. In this section, we will discuss the properties of metals and shop methods for testing various metals.

20-2. **Properties.** Properties of metals simply means the characteristics that allow them to be worked without failing. Several properties such as tensile strength, elasticity, ductility, and hardness are properties to consider when selecting a metal for a job.

20-3. *Tensile strength.* Tensile strength is a term relating to a property of metal. The meaning concerns how much stress, measured in pounds of force, the metal will withstand under a direct, straight pull. The length of the material doesn't have any effect on the tensile strength. Normally, when a piece of material is being tested for tensile strength, a round piece of material 0.505 inch in diameter and 2 inches long is used. An example of testing for tensile strength is to secure a piece of metal at one end (in the vertical position) and hang a weight on the other end until the metal separates. The amount of weight that is applied before the metal separates divided by the cross-sectional area is its tensile strength in pounds per square inch.

20-4. *Elasticity.* Elasticity means how much force of pull, bend, twist, or squeeze a piece of material will stand and yet return to its original shape. When a piece of rubber is stretched, it will return to its normal shape. And most metals will stretch and return to their original shape but not as much as rubber. When metals are stretched beyond their elastic limits, they usually remain in the stretched condition. The elastic limit is the point just before the metal reaches the permanent stretched condition. A metal that is between its elastic limit and breaking point is in a stage called the yield point. An example of this stage is where the metal has been bent or changes shape.

20-5. *Ductility*. Ductility is a property of metal that allows it to be permanently bent or formed without breaking. A good ductile material is one that can be permanently deformed without breaking or cracking and yet remain in the formed stage after the force has been removed. A material that is ductile is also malleable or pliable. Ductile and malleable metals can be thinned by rolling or hammering; however, most metals become hard when worked, and the tensile strength is increased. An example of a metal that is very ductile and malleable is copper.

20-6. *Brittleness*. Brittleness is a property of metal that allows very little bending before breaking. You are familiar with how a piece of glass will break when enough pressure is applied. A piece of metal that is brittle will act the same way. A metal that is brittle *is not* ductile. A good example of a brittle metal is cast iron, which breaks very easily when bent or struck with a hammer.

20-7. *Toughness*. Toughness is a term used for metals that will withstand force. You have no doubt used this term for something that was very strong but pliable. Toughness is a property that allows a metal to bend, twist, etc., without tearing or breaking.

20-8. *Hardness*. Hardness is the penetration resistance of a metal to an applied force. Hardness and toughness of a metal are much alike, since metals with such properties will withstand considerable hammering. The word "hard" also implies that the metal is solid or firm. A good example of a hard metal which you will be using is stainless steel.

20-9. **Shop Methods of Testing Metal Properties.** Metals can be tested in the shop for their properties. We will discuss a few tests that you can use to find the properties we have discussed. Manufacturers have machines for making tests and have tested the metals before shipment. The following tests will help you to select the best metals for a job.

20-10. *Elasticity test*. The elasticity test can be done in the shop by placing a piece of sheet metal in a vise. The metal should be around 1 inch wide and 8 inches long and should be clamped in the vise with the width of the material horizontal to the floor so that the material extends out of the jaws about 6 inches. Using a hammer or mallet, you should strike the metal about 2 inches from the end that is sticking out of the vise. The blow does not have to be too severe, and usually the weight of a 12-ounce tinner's hammer dropped from a height of 6 or 8 inches will be enough force. If the metal springs back to its original shape, you have a piece of metal that has good elasticity; if it does not return to its natural shape, but bends, it has poor elasticity.

20-11. *Ductility test*. The ductility test can be performed in much the same way as the elasticity test. Place a piece of sheet metal, about the same size as that used in the elasticity test, in the vise with the width of the material horizontal to the floor. One end of the material should extend from the jaws of the vise about 6 inches. You can use a pair of common pliers or vise grips to clamp on the metal about an inch from the end. Twist the metal about 180°, then release it. If it springs back, you have a piece of material with low ductility. If the material stays in the position, the metal has good ductility. On each test, check the metal for signs of cracks. Work the material back and forth several times; if it seems to harden each time, you have a piece of material that hardens as it is worked.

20-12. *Brittleness test*. The brittleness test can be performed in the shop with the use of a vise and pliers. This test is similar to the ductility test, except that if the metal breaks when bent the metal is considered to be brittle. In making these tests, you *should not* make an attempt to bend the metal with your hands. The sharp edges on the material may cut your hands and fingers.

20-13. *Toughness test*. The toughness test can be made in much the same way as the brittleness test, but take into consideration the thickness of the material you use. If you notice that considerable force is required as the metal is bent, you have a piece of material that has good toughness. Work the material back to the starting position and try the bend with a sudden jerk. This is another way to test for toughness, since tough metals can withstand such sudden forces.

20-14. *Hardness test*. The hardness test can be made in the shop with a center punch and hammer. Lay the metal flat and test by placing the punch point on the metal and striking the punch with the hammer. As the material is punched, you can tell how hard the material is by the indentation made by the punch. The deeper the punch mark, the softer the material. The reason for a slight blow is that some materials may be harder than the punch.

20-15. The tests we have explained will help you determine the properties of the metals you will use in the sheet metal shop. You should try several pieces of metal in the shop to get an idea of what we have discussed.

21. Ferrous Metals and Alloys

21-1. In this section, we will help you identify ferrous metals and alloys. Each ferrous metal will be explained separately.

21-2. **Identification.** Ferrous metals are composed chiefly of iron and include pig iron, cast iron, wrought iron, carbon steel, and various steel allows.

21-3. *Alloy steels.* Alloy steels have elements other than carbon added to improve the properties of the base metal. Some of the elements that are added to iron include nickel, chromium, zinc, tungsten, and silicon. Generally, alloys are harder than the base metal and have better corrosion resistance than the base metal. For instance, nickel and chromium have good resistance to corrosion.

21-4. *Carbon steel.* Carbon is added to metals to make them harder without using one of the alloys described earlier. A metal having low-carbon content is ductile and easy to bend. Metals having high-carbon content are hard to bend. The properties of high-carbon steel can be changed by annealing, hardening, or tempering. We will discuss these later in the chapter.

21-5. **Dead Soft Steel.** Dead soft steel, or wrought iron as it is sometimes called, is a low-carbon steel. It is commonly called black iron. Dead soft steel is corrosive and must be painted or coated with zinc or tin. It has good forming qualities and is used often in the sheet metal shop.

21-6. *Black iron.* Black iron is a dead soft steel available in sheets of various sizes and thicknesses. You will probably use it in thicknesses ranging from 30 to 16 gage; in sheet widths of 30", 36", and 48"; and in sheet lengths of 8' and 10'. Sheets thicker than 16 gage can also be obtained in widths of 48" and lengths of 8' or 10'. (Gage is a thickness measurement for sheet metal. The thickness gage will be discussed in another volume.) Black iron can be worked cold on the machines in the shop and may be bent up to 180° without breaking.

21-7. *Galvanized iron.* Galvanized iron is the same basic metal as black iron, except that galvanized iron has a coating of zinc to protect the base metal from corrosion. Like black iron, it has good forming qualities—and you will probably use it more than any other sheet metal. The bench stock in your shop will probably have several sheets of different gages and in widths of 36" and lengths of 10'.

21-8. *Tin plate.* Tin plate is tin-coated iron that has good corrosion-resistant qualities; however, it is considerably less resistant to corrosion than stainless steel or galvanized iron. Extensive exposure to corrosive conditions will require the tin-plated surface to be painted. Tin plate has good forming qualities and is available up to 20" in width and 28" in length.

21-9. **Stainless Steels.** The stainless steel that you will be using is a hard metal, resists scratches and corrosion, and will usually have a shiny finish. Stainless steel is an alloy of iron and other metals such as chromium, nickel, and small parts of silicon and manganese.

21-10. *18-8 stainless steel.* The 18-8 stainless steel is 18 percent chromium and 8 percent nickel; it is used in the sheet metal shop for jobs that require a metal that is resistant to corrosion. There are three types of 18-8 stainless steel, as shown in figure 113. Notice the percentages of carbon, manganese, silicon, chromium, and nickel.

21-11. The 18-8 stainless steel is used where resistance to chemicals, ease of cleaning, and freedom from contamination of food and dairy products are required. This stainless steel is also resistant to organic substances, such as fruit and vegetable juices. It is also resistant to zinc sulphate and X-ray developing solutions.

21-12. The 18-8 stainless steel has good forming qualities; however, some springback will be noticed during forming. The machinery in the shop should be checked before cutting or forming stainless steel, since the machines are rated for dead soft metals. Types of 18-8 stainless steel can be obtained in sheet sizes up to 48" wide and 144" long, depending on the gage thickness. For instance, 8 to 18 gage is available in widths

18-8. Stainless Steel Variations and Composition

Type	Maximum % Carbon	Maximum % Manganese	Maximum % Silicon	% Chromium	% Nickel
302	.15	2.00	1.00	17-19	8-10
304	.08	2.00	1.00	18-20	8-12
304 L	.03	2.00	1.00	18-20	8-12

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Figure 113. Stainless steel variations and composition.

of 24", 36", or 48", and in lengths up to 144". The following surface finishes are available.

• Hot Rolled Annealed and Pickled	(No. 1)
• Full Finish Bright Cold Rolled	(No. 2 B)
• Full Finish Dull Cold Rolled	(No. 2 D)
• Intermediate Polish	(No. 3)
• Standard Polish	(No. 4)
• Standard Polish Tampico Brushed	(No. 6)
• Highly Polished	(No. 7)

21-13. Type 302 of 18-8 stainless steel can be joined by almost all methods used in sheet metalworking. It can be riveted, spot-welded, soldered, or arc-welded. However, when arc welding is used to join the metal, you should not allow the metal to be overheated for long periods. The 18-8 stainless steel resists oxidation, if the metal is not allowed to overheat. (You will learn about these fastening methods in later volumes of this course.) Many jobs around food serving equipment will require welding, and different types of 18-8 stainless steel may be used. During welding the carbon in the metal precipitates, and the welded seam becomes exposed for corrosion to set in. Therefore, you should select the type (302, 304, or 304L) with the lowest carbon content.

21-14. In figure 113, you can see that type 304 stainless steel has a lower carbon content, and the chromium and nickel content is raised. This lowers the carbon precipitation during welding.

21-15. You will also notice that type 304L in figure 113 is another variation of 18-8 stainless steel. The carbon content is lowered to 0.03 percent. This variation is used when jobs require that the seams be welded and where maximum corrosion resistance is desired. All the variations of 18-8 stainless steel have the same forming qualities and can be obtained in the same finishes and sheet sizes. This completes our discussion of stainless steel; however, since monel resembles stainless steel, we will discuss it next.

21-16. *Monel.* Monel is an alloy that is sometimes mistaken for stainless steel because it resembles stainless steel and has many of its characteristics. Monel contains from 65 to 68 percent nickel; about 30 percent copper; and small quantities of iron, manganese, and cobalt. Monel is harder and stronger than nickel or copper, is ductile, and has good working qualities. Like stainless steel; it is corrosion resistant and can be worked cold; as it is worked, its tensile strength is increased.

22. Nonferrous Metals and Alloys

22-1. In this section, we will discuss nonferrous metals which do not have iron as a base. Copper, aluminum, zinc, and lead are nonferrous metals you will probably use in the sheet metal shop. Nonferrous metals have good resistance to corrosion; the surface will oxidize or tranish (change color) when exposed to weather but will not rust.

22-2. **Aluminum and Aluminum Alloys.** Commercially pure aluminum is a white, lustrous metal which ranks high in its resistance to corrosion. Commercially pure aluminum has a tensile strength of about 13,000 psi, but by rolling or using other cold-working processes, its strength may be approximately doubled. When it is combined with various percentages of other metals (generally copper, manganese, magnesium, and chromium), aluminum alloys are formed.

22-3. Aluminum alloys in which the principal alloying ingredients are either manganese, magnesium, chromium, or silicon show little sign of attack in a corrosive environment. Alloys in which a substantial percentage of copper is used are more susceptible to corrosive action. The total percentage of alloying elements is seldom more than 6 or 7 percent in the wrought alloys.

22-4. One disadvantage in using aluminum alloys is the difficulty of making reliable soldered joints. Oxidation of the surface of the heated metal prevents soft solder from adhering to the metal. There are special solders and fluxes that may be used to seal joints, or sometimes sealants are used.

22-5. Wrought aluminum and wrought aluminum alloys are divided into two general classes—heat treatable and nonheat treatable alloys. Nonheat treatable alloys are those in which the mechanical properties are determined by the amount of cold work introduced after the final annealing operation. The mechanical properties obtained by cold working are destroyed by any subsequent heating and cannot be restored except by additional cold working, which is not always possible. The "full hard" temper is produced by the maximum amount of cold work that is commercially practicable.

22-6. Wrought aluminum and wrought aluminum alloys are designated by a four-digit index and are shown in figure 114. The system is broken into three distinct alloy groups: 1xxx, 2xxx through 8xxx, and 9xxx (which is at present unused). In the 1xxx group the first number indicates that the alloy contains at least 99 percent pure aluminum. The second digit of the group indicates controls over the impurities contained in the alloy. Should the second number be zero, it would indicate no special control over

	AA Number
Aluminum--99.00% minimum and greater	1xxx
Aluminum Alloys, Grouped by Major Alloying Element	
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and Silicon	6xxx
Zinc	7xxx
Other element	8xxx
Unused Series	9xxx

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Figure 114. Aluminum alloy groups.

individual impurities. Digits 1 through 9, however, when assigned consecutively as needed for the second number in this group, indicate that particular number of controls over individual impurities in the metal.

22-7. The last two digits of the 1xxx group are used to indicate the hundredths of 1 percent above the original 99 percent designated by the first digit. Thus, if the last two digits are 30, the alloy would contain 99 percent plus 0.30 percent of pure aluminum, or a total of 99.30 percent pure aluminum. Examples of alloys in this group are:

- 1100—99.00 percent pure aluminum with one control over individual impurities.
- 1130—99.30 percent pure aluminum with one control over individual impurities.

22-8. In the 2xxx through 8xxx groups, the first digit indicates the major alloying element used in the formation of the alloy, as shown in figure 114.

22-9. In the wrought form, commercially pure aluminum is known as 1100. It has a high degree of resistance to corrosion and is easily formed into intricate shapes. Like other materials, aluminum becomes stronger and harder as it is rolled, formed, or otherwise cold worked. Since the hardness depends on the amount of cold work done, 1100 and wrought aluminum alloys are available in several strain-hardened tempers. The soft or annealed condition is designated 0, and the full hard is designated H18, with intermediate tempers from H12 to H16. The aluminums you will use are 1100 and 3003, which we will discuss in the following paragraphs.

22-10. *1100 aluminum.* The 1100 aluminum is 99 percent pure and has a tensile strength of 13,000 psi in the annealed condition. The 1100–H16 aluminum has a tensile strength of 20,000 psi and is used often for the fabrication of duct work, since the same tools that are used for galvanized iron can be used. Some sheet metalworkers prefer 1100–H12, which has a tensile strength of 15,500 psi, or 1100–H14, which has a tensile strength of 17,500 psi, for duct fabrication. These three alloys have good forming qualities.

22-11. *3003 aluminum.* The 3003 aluminum is used often in the fabrication of ducts. In the annealed condition it has a tensile strength of 16,000 psi. The 3003–H14 (half hard), which has a tensile strength of 21,500 psi, and 3003–H16, which has a tensile strength of 25,000 psi, are used where extra strength is required. These two 3003 types do not have the forming qualities of 1100–H14 and 1100–H16, and the joining method to be used should be considered when choosing the type. Alloys 1100–H18 and 3003–H18 (full hard) are good for jobs that do not require forming. Many shops use these types for signs, since aluminum resists corrosion much better than galvanized iron.

22-12. Aluminum is much lighter than black iron or galvanized iron and has replaced them for

Nearest Gage	Decimal Thickness	Ounce Per Sq Ft	Sheet Weight in Pounds, Size and Thickness				
			14"x48"	24"x48"	30"x60"	36"x72"	48"x72"
31	.0107	8	2.33	4	6.25	9	12
29	.0134	10	2.91	5	7.81	11.25	15
26	.0188	14	4.08	7	10.93	15.75	21
24	.0215	16	4.66	8	12.50	18	24
22	.0269	20	5.83	10	15.62	22.50	30
18	.0538	40	11.66	20	31.25	45	60
16	.0645	48	14	24	37.50	54	72

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Figure 115. Copper sheets, thickness, weight and size.

many jobs where weight is a concern. Your shop will probably stock a few sheets of aluminum in the 1100 and 3003 types, which are usually 30", 36", or 48" wide; 8' or 10' long; and in various thicknesses. The thickness of aluminum sheets is measured in decimals rather than gage. Here are some examples of the comparison of gage and decimal equivalents: 16 gage is 0.059, 20 gage is 0.031, 24 gage is 0.020, and 26 gage is 0.015. These are a few of the popular thicknesses which you will probably use from time to time.

22-13. **Copper and Copper Alloys.** Copper is very malleable and is easily worked. As it is worked, it becomes hard (work hardened) but can be softened by annealing, a process which we will discuss later in this chapter. Its thickness is referred to as weight in ounces per square foot. In figure 115 you can see the gage and decimal equivalents, ounces per square foot, and sizes of various copper sheets. Some of the popular sizes that are used in sheet metal shops are included. Copper resists corrosion and is used where long life of the metal is required. Copper is often added to other metals such as aluminum to increase the corrosion resistance of the metal. Copper holds heat well; you have probably noticed that the soldering coppers (irons) in the shop are made of copper. Copper is expensive, and consideration should be given to the job before deciding to use it.

22-14. *Brass.* Brass is an alloy of copper and one of the most widely used copper alloys. Brass is resistant to corrosion, since it is usually composed of 50 percent copper and 32 to 50 percent zinc. It has a bright yellow color and is easily formed; it is available in sheets of various sizes and thicknesses. The thickness is measured in gage rather than weight. Brass is soft and can be cold worked.

22-15. *Bronze.* Bronze is another copper alloy and is composed of copper with tin or zinc. Bronze is harder than brass and is expensive because of the tin content. You will usually find bronze in bar or round stock rather than in sheets.

22-16. **Lead.** Lead is a very soft metal and works much more easily than any of the metals we have already discussed. It is alloyed with tin to make solder, which you will use often. Solder is discussed in another volume. As a sheet metalworker you may be required to line an X-ray room with lead, since it resists radioactive rays. Lead also resists chemicals and is used around sewer vents. Lead can be purchased in rolls or in sheet form in various sizes. It has very little strength and should not be used where strength is required. Lead is very heavy, and its weight should be considered when used.

22-17. **Zinc.** Zinc is a medium hard metal used chiefly to alloy with other metals and to coat black iron for corrosion resistance. When iron is dipped in melted zinc and allowed to cool, the zinc forms crystals which make a spotted appearance on the surface. You have probably observed a "G.I. can" that is zinc-coated to resist corrosion. Zinc hardens when worked; it can be annealed by heating and slow cooling. Zinc is also used to cut raw acid (soldering flux), which you will study in another volume of this course.

22-18. This completes our discussion of metals, except for the chemical symbols used for metals. The symbols for ferrous and nonferrous metals are shown in figure 116. The melting point for each of these metals will be discussed in the next section, which concerns annealing, hardening, and tempering.

23. Heat Treating

23-1. Heat treating of metals is done to change the properties of the metal. It is done by annealing, hardening, and tempering. In this section, we will discuss each of these processes and give examples of treating some of the metals you learned about earlier in this chapter.

23-2. **Annealing.** The annealing of metals is a process of heating the metal to a cherry red color and cooling slowly. Annealing reduces brittleness, since it restores ductility, relieves stresses, and controls grain size. Copper can be annealed to increase its electrical conductivity. Copper is a metal that is cooled quickly as it is annealed by quenching (dipping) it in water; however, most other metals are cooled slowly. Don't confuse annealing with tempering, which we will discuss later.

23-3. To anneal steel, it is heated to a high temperature, approximately 1375°. (Since an ap-

Name	Symbol	Melting Point	Color
Aluminum	Al	1219° F	Silvery White
Iron	Fe	2700° F	Black
Nickel	Ni	2646° F	Shiny Silvery
Chromium	Cr	2939° F	Bluish White
Copper	Cu	1981° F	Reddish Brown
Silicon	Si	2588° F	....
Zinc	Zn	787° F	Bluish White
Lead	Pb	621° F	Bluish Gray
Tin	Sn	449° F	Shiny Silver

Figure 116. Symbols, melting point and col
ferrous and nonferrous metals.

For Tempering		
Degree Farenheit	Color For Related Degree	Kind of Material
430	Yellow	Scrapers, Hammers
470	Straw	Punches, Twist Drills, Reamers
500	Brown	Drift Punches
540	Purple	Cold Chisels, Center Punches, Rivet Sets
570	Blue	Screw Driver

530-1907

Figure 117. Heat and color for tempering tools.

proximate degree is being reached, a cherry red effect will appear on the heated area as the metal reaches approximately 1375°.) It is important that the steel reaches this temperature so that the hardness will be removed.

23-4. The steel is allowed to cool slowly, and the slower the metal cools the more effective the annealing process will be. The thickness of the material has some effect on the cooling time, which can range from 5 to 24 hours. To cool metals slowly, a sand pit or asbestos annealing box will more than likely be used in your shop. The piece being annealed should be allowed to cool in the annealing box until it reaches room temperature before being removed. The piece should be well buried in the annealing box so that the cool air in the room will not reach the hot metal.

23-5. **Hardening.** Hardening is a process of changing the property of metals to make them harder. Hardening steels, especially high-carbon steel, is done by heating the metal to a cherry red color and cooling fast. The metal is cooled fast in a quench tank of oil, salt brine, or water. As the piece is quenched, it is circulated in the solution to insure even cooling. The heating and quenching process gives the piece of metal a fine grain structure, extreme hardness, greater strength, and less ductility. Metal quenched in water is hard but brittle; salt brine makes a good quench solution, but oil is better than salt brine or water.

23-6. **Tempering.** Tempering is a process of restoring temper to a metal or adding temper to a metal to change the property. Tempering is also done to reduce the excessive hardness that is often produced during the hardening process. Tempering is done by heating the metal to a specific temperature. In figure 117, you can see a chart of the tools that may require tempering. You should learn to recognize the surface appearance of the material when it reaches the desired temperature.

23-7. A clean surface is important when you are tempering metals. If the surface is not clean, you will not get an accurate surface color as the materal is heated. The surface can be cleaned with a piece of abrasive cloth or paper until it has a bright finish. After the surface has been cleaned and heated to the desired temperature, the metal is dipped in water or oil and circulated.

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Answers For Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate the numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

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118 Nonferrous Metals and Alloys; Heat Treating; pages 88–91

MODIFICATIONS

Pages 3-5 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 2

Objectives: Given the fundamental principles of shop mathematics, to demonstrate the ability to work typical problems involving graduated scales, fractions, decimals, equations, formulas, lines, angles, and plane and solid figures.

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1. Fill in the blanks. Use the graduated scale illustrated in figure 4 of the text and determine the distance between the numbers and letters listed below. (6-4: Fig. 4)

   a. 1 to 2 __________
   b. 2 to 3 __________
   c. 3 to 8 __________
   d. 4 to 8 __________
   e. *b* to *c* __________
   f. *c* to *d* __________
   g. *e* to *f* __________
   h. *b* to *f* __________

2. If you are to drill six 1/16-inch holes in a piece of metal 1¼ inches apart, what will be the reading on a rule being used to measure between the center of the first and last holes? (6-5)

3. Convert the following improper fractions to mixed numbers. (7-2)

   a. 11/8 =
   b. 21/16 =
   c. 6/4 =

4. Convert the following mixed numbers to improper fractions. (7-3)

   a. 1¼ =
   b. 4 1/8 =
   c. 12½ =

5. Reduce the following fractions to the lowest terms. (7-4)

   a. 4/8 =
   b. 6/16 =
   c. 24/32 =

6. A piece of sheet metal has six holes drilled along a straight line, and each hole is spaced 6 1/8 inches apart (center to center). What is the distance between the centers of the end holes? (7-5)

7. Multiply the following fractions. (7-5, 6)

   a. ½ × ½ =
   b. 14 × 5/16 =
   c. 4/16 × 6/8 =

8. Subtract the following fractions. (7-9)

a. 30¼ – 15¾ =
b. 30½ – 14¼ =
c. 27 – 12 1/8 =

9. A piece of sheet metal 4 inches by 7½ inches has two holes drilled along a 7½-inch straight line drawn down the middle of the sheet. If the center of the first hole is 1 1/8 inches from end *A* of the sheet and it is 3¾ inches to the center of the second hole, how far is it from the center of the second hole to end *B* of the sheet? (7-9)

10. Change the following fractions to decimals. (8-6)

a. ¼ =
b. 3/16 =
c. 5/8 =

11. Use figure 5 and locate the correct decimal equivalent for the following fractions. Write each of the numerical decimal equivalents and how it is read. (For example: 5/100 = 0.05, or *five hundredths.*)

a. 3/16 = __________or______________
b. 7/32 = __________or______________
c. 15/16 = __________or______________

(8-4, 8; Fig. 5)

12. If you are making a collar for a transition with a 10" diameter outlet and a width of 4", how long will the collar be, less seam allowances? (9-6; 10-25)

13. Matching. The following abbreviations are used in mathematical formulas. Fill in each blank with a number listed below that identifies the corresponding abbreviations. (9-6)

a.	__________	Plus sign.	1. (π)
b.	__________	Square of a number.	2. (+)
c.	__________	Multiply and divide.	3. (πr^2)
d.	__________	Equality sign.	4. (=)
e.	__________	3.1416	5. (^{2})
f.	__________	Area of a circle.	6. ($\frac{bh}{2}$)

14. Transpose the equation $x = B + C$ to solve for B. (9-9)

15. Transpose the equation $x = B - C$ to solve for B. (9-10)

16. Transpose the equation $x = BC$ to solve for C. (9-11)

17. Transpose the equation $x = \frac{BC}{2}$ to solve for C. (9-12)

18. Fill in the blanks. Mensuration is that branch of geometry that deals with the ____________________ of lines, angles, surfaces, and solids. Plane figures have __________________ dimensions, and solid figures have ______________ ____________________________ dimensions. (10-1)

19. Matching. Use the triangle shown in figure 7 and select the number listed below that identifies the corresponding description. (10-2–10; Fig. 7)

a. ______________ Parallel lines.
b. ______________ Vertex.
c. ______________ Perpendicular line.
d. ______________ Right triangle.
e. ______________ Isosceles triangle.
f. ______________ 90° angle.
g. ______________ Acute triangle.
h. ______________ Hypotenuse.
i. ______________ Base.
j. ______________ Altitude.

1. *A*
2. *DAC*
3. *DAC*
4. *BAC*
5. *AB* to *DC*
6. *DC* of triangle *DAC*
7. *AB* of triangle *DAC*
8. *AC* of triangle *BAC*
9. Angle *B* of triangle *DAB*
10. Not shown.

20. What is the area of a square that has one side 23½ inches long? (10-12)

21. What is the length of the sides of a square which has an area of 25 inches? (10-12)

22. What is the area of a rectangle 7.25 inches by 12.75 inches? (10-13)

23. If the base of the rhomboid shown in figure 9 is 12 inches and the dashed lines are 7 inches, what is the area of the rhomboid? (10-14; Fig. 9)

24. Agree-Disagree. The area of any parallelogram equals the product of the base times the height (altitude).(10-12–15)

25. In the rhomboid, rhombus, and trapezoid shown in figure 9, what dimension is indicated by the dashed lines? (10-14–16; Fig. 9)

26. Fill in the blanks. To find the area of a trapezium or any other irregular polygon, divide it with ______________ lines into simpler forms such as ______________. The areas of these parts may then be calculated, and the ______________ of the various areas will be the total area of the figure. (10-17)

27. Matching. Common polygons are listed below. Select the number that identifies the corresponding description and write it in the blank space. (10-18)

a. ______________ Hexagon. 1. Five sides.
b. ______________ Octagon. 2. Six sides.
c. ______________ Pentagon. 3. Seven sides.
d. ______________ Heptagon. 4. Eight sides.

28. Mark out the incorrect italicized word. A simple way to construct a regular polygon is to draw a circle, then draw the polygon *inside outside* the circle. (10-19)

29. What is the length of each side of an octagon which has a diagonal of 12 inches? (10-20, 21)

30. What is the area of an octagon which has a diagonal of 12 inches? (10-22)

31. What is the formula for finding the circumference of a circle? (10-25)

32. What is the radius of a circle that circumscribes a hexagon whose diagonal is 6¼ inches? (10-26, 27; Figs. 11, 12)

33. What are two formulas for determining the area of a circle? (10-28)

34. Fill in the blanks. The space inclosed by the three dimensions of a solid is expressed in ______________ inches, ______________ feet, etc. (10-34)

35. Matching. Use figure 12 and identify parts of the circles which are listed below. Select the corresponding numbers and write them in the appropriate blanks. (10-23–35; Fig. 12)

a. ______________ Circumference
b. ______________ Diameter
c. ______________ Radius
d. ______________ Arc
e. ______________ Chord
f. ______________ Tangent
g. ______________ Sector
h. ______________ Segment

1. *d*
2. *G*
3. *H*
4. *r*
5. *EF*
6. *AB*
7. *C* and *H*
8. Not identified in the illustration

36. Agree-Disagree. Prisms have sides that are parallelograms and ends that are triangular, square rectangular, or other polygon shapes. (10-35)

37. A cylindrical tank 12 feet tall and 6 feet inside diameter stands on end. If it is filled with water to a depth of 8 feet 6 inches, how many cubic feet of water does it contain? (10-39)

38. What is the formula for determining the curved area of a cylinder? (10-40)

39. What is the total outside area (including base) of a pyramid that has a slant height of 30 inches and a base 20 inches square? (10-12, 43)

40. What is the formula for determining the volume of a cone? (10-45)

41. What is the surface area of a sphere that has a diameter of 14 inches? (10-49)

CHAPTER 3

Objectives: To apply a knowledge of the various measurement and layout tools by answering questions on the proper use of tools, and by solving problems typically encountered by the sheet metal specialist.

1. What are the smallest fractional subdivisions of the 6-inch rule shown in figure 18? (11-4; Fig. 18)

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2. In figure 18, what is the width of the block being measured? (11-4; Fig. 18)

3. According to the circumference rule illustrated in figure 20, what is the circumference of a circle that has a diameter of 6 inches? (11-6; Fig. 20)

4. When using a circumference rule to measure the circumference of a 55-gallon drum, will the circumference reading be high or low if the inch scale side of the rule (instead of the circumference side) is placed on the exact center of one of the ends of the drum? (11-6)

5. Agree-Disagree. The 8-foot power-return steel tape with an adjustable hook can be used for inside or outside measurements without compensating for the thickness of the hook. (11-9)

6. If the inside measurement of a heating duct is 3' 6" x 18" , what will be the readout measurements at the case of an 8-foot power-return steel tape equipped with a self-adjusting hook? (11-9)

7. If you are making an outside measurement with an 8-foot power-return steel tape with a self-adjusting hook, what will be the readout measurement on the tape if the actual distance is 72 inches? (11-9)

8. Which attachment of the combination set, when installed on the blade, can be used to locate the center of a circular object? How? (11-13)

9. What are the three attachment heads of a combination set, and what is one example of a use for each one? (11-10–14; Figs. 24, 25)

10. Using a framing square and spirit level, you determine that a roof has a 3-12 pitch; at what points on the body and tongue of the square will the roof line pass through? (11-16; Fig. 27)

11. What are three uses of the framing square in sheet metalwork? (11-15–17)

12. How can a framing square be used to locate the center of a circle? (11-17; Fig. 28)

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13. If inside, outside, and hermaphrodite calipers are not recommended for precision measurements, what measuring tool is recommended for measurements that involve fractions smaller than the calibrations on steel rules? (11-18, 22)

14. What is the size of the stock being measured in figure 29? (11-19; Fig. 29)

15. A block of metal is supposed to be 2 inches long, 1¼ inches wide, and ½ inch high. What type of caliper should be selected to verify the measurements? (11-19)

16. In figure 30, if a measurement was taken the wrong way, will it be too much or too little? (11-20; Fig. 30)

17. What caliper would be best suited to determine the distance between two small steam pipes which extend through a wall and are less than 3 inches apart? (11-20)

18. If a micrometer such as that shown in figure 34 is used to measure the thickness of a sheet of 22-gage sheet metal (thirty-one thousandths thick), what numbers and marks will be exposed on the barrel, and what mark on the thimble will be aligned with the horizontal line on the barrel? (11-27; Fig. 34)

19. Fill in the blanks. In figure 35, the reading indicated by view A is ____________ inch; view B is ____________ inch; view C is ____________ inch; and view D is ____________ inch. (11-28; Fig. 35)

20. What are the settings of the three scales on a vernier micrometer, such as shown in figure 36, when 26-gage sheet metal (0.0179 inch) is measured for thickness? (11-32; Fig. 36)

21. Fill in the blanks. The readings of the vernier micrometer scales shown in figure 37 are as follows: view B is ____________ inch, view C is ____________ inch; and view D is ____________ inch. (11-32; Fig. 37)

22. Fill in the blanks. The level shown in figure 38 contains six vials—two for horizontal ____________ and four for vertical ____________________ . (12-3; Fig. 38)

23. Fill in the blanks. When using a framing square to determine the pitch of a roof as shown in figure 28, the lower________________ ____________________vial is used to level the body of the framing square. The same results could be obtained by holding the level against the tongue of the square and reading either one of the lower _______________ ____________________ vials. (12-3; also 11-16; Fig. 27)

24. Using the 1" = 1' scale of the architect's scale illustrated in figure 39, what is the actual length of a line that measures from 8 to the left of the zero mark to 9 from the right of the zero mark? (12-6, 7; Fig. 39)

25. What is the actual size (length and width) of a rectangular window drawn on a 6" = 1' scale working drawing if the following measurements are made with an architect's scale: The length of the window measures from zero to number 6 on the right, and the width measures from number 3 on the right to the halfway mark on the reduced scale on the left of zero? (12-8; Fog. 39)

26. Why is the pencil compass not as accurate as dividers for transferring measurements? (12-11, 12)

27. If the top of a stainless steel steamtable is being replaced, should dividers or a pencil compass be used to scribe the circles for the holes to be cut? (12-13)

28. Bisecting a line and drawing a perpendicular as shown in figure 44 is a basic operation which is used in many graphic solutions. Describe how a line is bisected and a perpendicular drawn using a pencil, straightedge, and pencil compass. (12-16; Fig. 44)

29. Locating the center of a circle as shown in figure 48 uses the procedure illustrated in figure 44. Can the procedure illustrated in figure 45 also be used to find the center of the circle shown in figure 48? Why? (12-16, 17, 20; Figs. 44, 45, 48)

30. If a pencil, straightedge, and pencil compass are used to draw figure 52, which operation is performed with the compass? (12-24; Fig. 52)

31. Which of the angles shown in figure 54 is used to draw perpendicular lines? (12-27; Fig. 54)

32. In figure 55, what will be the angle formed if one line is drawn from the index point on the protractor to the 50° mark on the outer scale and another line is drawn from the index point to the 170° mark on the outer scale? (12-28; Fig. 55)

33. If a pattern you are making requires that a 40° angle be drawn to the right side of a vertical line, this line will be drawn from the index point on the protractor to what degree mark? (12-28; Fig. 55)

34. What is an advantage of holding templates in place with clamps while the scriber is used? (12-29)

35. If a paper pattern for a metal box includes locations of rivet holes, should a template of the same pattern also have rivet hole locations? Why? (12-29)

36. The grid in figure 57 represents ½-inch squares. What is the horizontal distance between the first dot on the left and the dot at the end of the curved line? What is the vertical distance? (Fig. 57)

37. The grid shown in figure 57 has four dots that are not connected with the curved line. If these dots are connected, it will form an ogee (S) curve. Can the irregular (French) curve be used to connect these points to form an ogee curve? (12-30; Fig. 57)

38. Fill in the blanks. Trammel points are sometimes called ________________ ________________ because the adjustable points may be positioned along a rod or beam to ______________ measurements or for laying out large ___________ and ___________ in a manner similar to that used with dividers. (12-31)

39. How can a circumference rule and trammel points be used to scribe a circle 110 inches in circumference, and what will be the approximate diameter? (12-31, also 11-6)

40. How can a plumb line be used to determine if the vertical plumb vials of a level are really plumb? (12-32)

41. Will a reference line established by a plumb line be perpendicular or parallel to the horizon? (12-32, 33)

42. Fill in the blanks. Before installing a downspout on the side of a building you are told to use a chalk line and make a vertical powdered chalk reference line on the building. This can be easily and quickly accomplished by attaching a ______________ ______________ to the chalk line. (12-32, 33)

CHAPTER 4

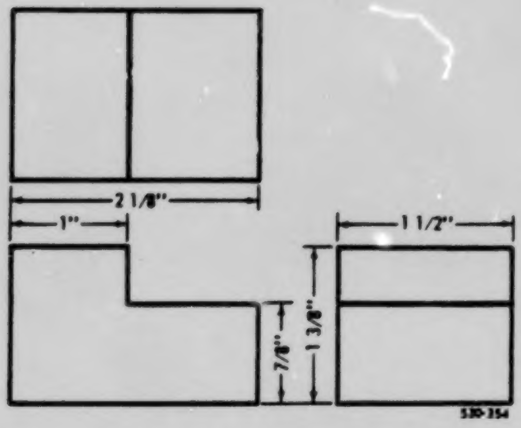
Objectives: To show a knowledge of working drawings, terminology, symbols, and specifications; to apply this knowledge by solving typical drawing problems.

1. If you are to fabricate and install air-conditioning ducts in a two-story building, would you obtain the vertical dimensions and horizontal dimensions from the plan, elevation, or detail view? (13-6–8)

2. Which of the following contain orthographic projection views: figure 60, 61, 62, 63, or 64? (13-1–9; Figs. 60, 61, 62, 63, and 64)

3. Use the three orthographic views illustrated in the figure for this exercise and answer the following questions:

   a. What is the length of the block shown in the plan view? (14-3)
   b. What is the width of the highest portion of the block shown in the side elevation view? (14-4)
   c. What is the greatest thickness of the block shown in the side elevation view? (14-5)
   d. What is the height of the front portion of the block shown in the front elevation view? (14-6)
   e. What is the depth of the cutaway portion of the block shown in the side elevation view? (14-7)



CRE Figure 1. For Review Exercise 3, Chapter 4.

4. If the shoulders of the groove shown in figure 65 have dimensions of 1¼" length, and ½" width, and ½" height, what is the thickness and width of the block if it has a height of 3¾" ? (14-3–7, 12; Fig. 65)

5. What is represented by the invisible outlines which are drawn in the plan view of figure 62? (14-10; Fig. 62)

6. What is the heel radius of a 90° rectangular elbow (shown in a plan view) which has a throat radius of 3" and connects two sections of 3" X 6" rectangular duct? (14-14, 17)

7. Beside each of the following items draw the designated geometric figure, then add the specified dimensions using the appropriate dimension and extension lines. (14-12–19)

   a. 60° angle.
   b. 15° angle.
   c. 6" circle (two methods).
   d. ¼" hole (two methods).
   e. 3" and 6" radii of an ogee curve.
   f. Pyramid with 6" vertical height and 3" X 3" base.

8. What is the height and width of a rectangular duct which has the dimensions 12" X 20" written on a duct shown in the plan view? (15-3)

9. When looking at the symbols on a plan view of a working drawing, how can you distinguish a supply duct from a return duct? (15-5, 9; Fig. 71)

10. The furnace shown in figure 62 has two plenum chambers; one plenum has a symbol indicating its function. What is the appropriate symbol for the unmarked plenum chamber? (15-9; Fig. 62)

11. What is represented by the curved symbols used in the two branches of the supply duct shown in figure 62? (15-16; Fig. 62)

12. What is meant on a working drawing by a register symbol (supply outlet) that has the following information: T & BR 20 X 12-EA 700 cfm? (15-24; Fig. 75)

13. What is the total length of each inside and outside corner of the gravel stop and fascia shown in figure 77? (16-5; Fig. 77)

14. In figures 77 and 78, how much expansion is allowed for each running section of aluminum and each running section of copper gravel stop and fascia? (16-5; Figs. 77 and 78)

15. Your shop is to replace aluminum gravel stop and fascia like that illustrated in figures 77 and 78. The dimensions of the dormitory building (length of the gravel stop and fascia) are 181'8" long and 30'8" wide. (16-5; Figs. 77, 78)

    a. What will be the lengths of the running sections to be made up for the ends of the building?
    b. How many expansion joints will be needed for all four sides?

16. In figure 77, what is the width of the inner flange of the gravel-stop that extends under the gravel and asphalt roof coating? (16-5; Figs. 77 and 78)

17. From figure 77, you can see that the 10-foot running sections of aluminum gravel stops and fascia are held in place with 1½" flathead wood screws at the midpoint and by the expansion joints at each end. Why will this method of fastening be adequate during windy conditions? (Figs. 77, 78, and 79)

18. One of the notes in figure 77 specifies that 1½" flathead wood screws are to be used at the midpoints of the aluminum running sections. Although this seems to contradict the general specification for nails spaced not over 3 inches on centers, examine figures 77 and 79 and explain why there is not a discrepancy. (16-5; 17-4; Figs. 77, 79)

CHAPTER 5

Objectives: To show a knowledge of the correct methods for transferring patterns to metal; also, the practical application of the basic principles of sheet metal layout work, including the use of the parallel line, radial line, and triangulation layout methods.

1. In developing a pattern for a rectangular duct, what descriptive information is omitted from a working drawing that shows the duct to be 16 inches wide and 12 inches high? (18-2)

2. If the plan view and elevation view are not available, what information from the part will you need to draw a sketch and begin a pattern? (18-2, 4)

3. The replacement of a roof jack tapers from a 12" × 12" base to a 6" diameter outlet. What are two ways the height can be determined, and which layout method must be used to develop the pattern? (18-2, 6)

4. What determines the layout method to be used for developing a pattern? (18-6)

5. A blueprint or working drawing requires a 30° elbow with a 6-inch diameter: what layout method should be used to develop the pattern? (18-6)

6. In figure 82, which views illustrate the true length of the round duct? (18-9; Fig. 82)

7. After transferring the length of the element lines to the pattern stretchout in figure 83 and using an irregular (French) curve to draw in the miter line, you notice that element lines 3 and 11 in the stretchout are too long, causing two humps in the miter line. What is the likely cause if you have checked and found the elevation view to be correct? (18-12, 14; Fig. 83)

8. What is the heel radius of the elbow shown in figure 86? (18-19; Fig. 86)

9. Where will the seam of a Y-branch be located on pieces II and IV of a pattern such as that shown in figure 87? (18-22; Fig. 87)

10. The 45° elbow on a heater vent needs replacing. How many half and whole gores are needed from the pattern of a five-gore elbow? Why? (18-24; Fig. 86)

11. Agree-Disagree. The element lines of piece II in figure 87 are 45° to the element lines of piece III, and the angle of the element lines for pieces I and V is also 45° to pieces II and IV. (18-25; Fig. 87)

12. If the two branches of a Y-branch are 30° to the trunk, what angle is required to return the element lines of the branches parallel to the element lines of the trunk? (18-25, 26; Fig. 87)

13. How many half plan views will you need to draw when developing a pattern for a T-joint that has an 8" main pipe and a 4" collar? (18-28; Fig. 89)

14. Fill in the blanks. The assignment is to make a pattern for a 90° T-joint with a 3" main pipe and a 3" collar (branch). The ________________ line method should be used to develop the pattern. The main pipe and ________________ are drawn to intersect at a 90° angle. The ________________ views are drawn and divided into equal spaces and the points projected to form the ____________ lines until they intersect one another. Their point of intersection forms the miter lines which are used to develop the patterns for the ____________ and ______________ by transferring the lengths to the stretchouts. (13-27–32; Fig. 89)

15. What determines the length of the stretchout arc of a cone when you are using the radial line method of pattern development? (18-33; Fig. 90)

16. Describe the appearance of a fabricated sheet metal component 36" long that has an inlet opening of 24" X 24" and an outlet opening of 18" X 18". (18-33, 39, 41)

17. A component fabricated in the sheet metal shop has an inlet opening of 24" X 24" and an outlet opening of 18" X 18". Its length, however, is less than the desired length. Where was the mistake made during radial line pattern development if the component should have been 36" long? How and why did the mistake cause the component to be short? (The mistake is not in the seam allowance or in the transfer of any distances to pattern.) (18-33, 37, 41; Fig. 94)

18. The true height and slant height of a pyramid are different lengths. Is this also true for the true height and slant height of a cone? Why? (18-43; Fig. 94)

19. Assume that you are to draw a pattern for a 5-12 pitch roof jack that tapers from a 10" diameter base to a 6" diameter top opening and has a vertical height of 12". The shape of this roof jack will be a variation of the irregular frustum shown in figure 106, except that the truncated top is perpendicular to the vertical height (centerline) and the base is truncated at an angle equal to a 5-12 pitch We suggest that you draw the elevation view, half plan view, and pattern for this roof jack, since this is a component that is frequently fabricated in the sheet metal shop. To draw the elevation view it is suggested that you start with a horizontal line 12" long with a 20" perpendicular line erected from the center point. The 5-12 pitch can be determined by drawing a line from one end of the 12" line to a point 5" above the other end. The sides of the frustum are projected upward from points 5" on each side of the center point of the horizontal line. From this start you should be able to draw the elevation view, remembering that the vertical height is the distance between the two truncation lines of the frustum.

a. In the elevation view, what is the centerline distance between the truncation lines, and what is the length of the upper truncation line? (18-44, 45)
b. How is the vertex point established? (18-44, 45)
c. What distance(s) on the elevation view determine where the top truncation line will be on the pattern? (18-44; Fig. 98)
d. In the elevation view which you have drawn, how are the true lengths of the element lines determined for the lower truncation line? (18-45)
e. In the pattern you have drawn, what is the length of the stretchout? (18-46)

20. In the pattern of figure 100, which element lines are the same length and why? (18-47; Fig. 100)

21. If a formed downspout connector made from the pattern shown in figure 100 is placed on the gutter radius and points 1 and 7 contact the gutter 1/8" before the other points, what mistake was made in the pattern development? (18-47; Fig. 100)

22. Agree-Disagree. The length of the element lines is the same length as the true length lines in triangulation layout. (18-50, 51)

23. If you have formed an oblique cone made from a pattern similar to the one shown in figure 105 and element lines 4 and 10 are found to be too long, what mistake was probably made in transferring the element lines to the true length chart? (18-54; Figs. 104, 105)

24. If a square-to-round transition pattern, such as that shown in figure 110, has been made, how can a framing square be used to check the pattern for accuracy? (18-61; Fig. 110)

25. If the two right triangles in the half pattern shown in figure 110 are joined, will they form an isosceles triangle? Why? (18-62; Fig. 110)

26. When a half pattern like that shown in figure 110 is transformed to metal, cut out, formed, and joined, how many isosceles triangles will result? (18-62; Figs. 109 and 110)

27. A working drawing shows a cone that is offset in two directions from center. Will a whole plan view or a half plan view be needed to develop the pattern? Can the same procedures be used to develop the true length chart and patterns as were used in figures 107 and 108? (18-66; also 57, 60; Figs. 106, 107, 108)

28. Why are seam allowances and additions made on patterns? (18-70, 71)

29. What determines the allowance for seams and additions? (18-71)

30. Why are the element lines, seam lines, and points which are marked on paper patterns transferred to the metal patterns? (19-1)

31. Why should a pencil instead of a scribe be used to transfer paper patterns to metal? (19-1, 2)

32. To transfer the pattern for a single seam round offset, such as that shown in figure 108, the pattern is marked as illustrated, then rolled end to end so that line 1-2 is again in alignment: and the transfer process is repeated, making one continuous pattern with line 1-2 in the center. Should this same procedure be followed to transfer the pattern of the oblique cone shown in figure 105? Why? (19-11; Figs. 105, 108)

CHAPTER 6

Objectives: To show a knowledge of the properties of ferrous and nonferrous metals and alloys; established methods of testing for these properties; and the heat-treating procedures of annealing, hardening, and tempering.

1. A work order and drawing submitted by the heating shop indicates that a soft metal gasket is required in a flange connection of a steam line. Which nonferrous metal would you select to make the gasket? Why? (20-5; 22-6; 23-2; Fig. 116)

2. If you are applying very little force on a drift punch to align bolt holes in a frame and the punch breaks suddenly, which two desirable properties of metals are missing? (20-7)

3. Fill in the blanks. A chisel is being used to cut ¼" diameter stove bolts. The head mushroomed easily; therefore, the chisel has lost its ______________ and _________properties. The head is examined and you notice that the mushroomed edges are breaking away from the chisel; therefore, the head has become ________________________ . (20-6–8)

4. If the striking end of a cold chisel becomes mushrommed, what two desirable properties of metals are missing from the chisel? (20-7, 8)

5. Fill in the blanks. A 2" section of a 6" piece of sheet metal 1¼" wide is placed in a vise with the flat surface horizontal to the floor, and it is struck lightly with a hammer. If the metal springs back to its natural shape it has good _______________ properties, and if it bends easily it has good _______________ properties. Examination of the metal that sprang back to its original shape reveals its surface is highly polished and shiny. The metal you tested is _______________ steel. If the piece of metal had bent easily and had a reddish-brown color, it would have been ________ . (20-4, 5, 10, 11; 21-12; Fig. 116)

6. A work order requires that an inside fire door be covered with 24-gage sheet metal and that the cover be joined with grooved seams and painted. Which metal would you select for the job? (21-5, 6; Fig. 116)

7. A work order requires that a storage box measuring 24" wide, 48" long, and 30" high be made of 20-gage sheet metal. The box will be painted and stored inside the building. Which ferrous metal would you select to fabricate the box? (21-6)

8. A duct system for a combination heating and air-conditioning unit is to be fabricated using 24-gage sheet metal. The installation does not establish a minimum weight of the duct, and the metal does not have to be highly corrosion resistant. Which metal would you select for the fabrication? (21-5, 7)

9. A duct system to be fabricated has several offsets, elbows, and rectangle-to-round components in its makeup. The duct will be connected to a combination heating and cooling unit. The weight of the duct is not critical; 22-gage sheet metal will be used for the trunk line, and 24-gage for the branch connections. Which metal would be suitable for the fabrication? (21-5, 7)

10. Name a ferrous sheet metal that would be suitable to substitute for galvanized iron when fabricating gutters for a building. Why? (21-8)

11. While replacing a gutter you notice that the old metal surface appears to be zinc coated, but the surface lacks the crystal spots usually found on galvanized iron. What metal is the gutter likely made of? (21-8)

12. Why does stainless steel have better corrosion resistance than other ferrous metals? (21-10)

13. Specifications require that a highly polished and corrosion-resistant food serving line be fabricated and that the seams be welded for maximum corrosion resistance. Which metal grade and finish would you select? Why? (21-12, 13, 15; Fig. 113)

14. A corrosion resistant metal awning is to be fabricated and installed on a building. The awning is to be as light as possible and must have a tensile strength of 16,500 psi. Which metal would be suited for the job, since the design of the awning will require extensive forming? (22-10)

15. A heating duct is to be fabricated and installed. The specifications require the duct to have minimum weight and maximum strength. You check the working drawing and find that the metal must have ductile properties. Which metal would be selected for the fabrication? (22-10, 12)

16. A work order requires that gutters be installed on a permanent building. Which nonferrous metal would you select, since all joints are to be soldered? Why? (22-13)

17. Agree-Disagree. Lead is better material for covering fire doors than is galvanized iron. (22-16; Fig. 116)

18. If the plumbing shop requests a roof jack that resists chemicals and can be hand formed, which metal would you select to fabricate the jack? Why? (22-16)

19. Agree-Disagree. If the wash tank in an X-ray developing room is to be replaced, zinc-coated metal would be suitable. (22-17; also 21-11)

20. During installation of a galvanized iron duct system, several seams require soldering; you find that the soldering flux is too strong, causing an excessively dark soldered joint. What can be used to cut the acid? (22-17)

21. The shop method of testing metal for properties was used on a piece of reddish brown metal. The metal was worked until it became hardened; how can this metal be softened? Why? (23-2; Fig. 116)

22. If a piece of copper is heated and quenched in water and it does not become soft, what is the likely mistake? (23-2, 3)

23. If the surface of a screwdriver point is heated until it turns blue and is then dipped in oil, what are you restoring to the metal point? (23-6; Fig. 117)

24. A chisel cutting edge is being tempered by heating the edge to a purple color (540°) and dipping in oil; however, the tempering process fails, leaving the edge too hard. What is the likely mistake in the tempering process? (23-6, 7)

* Pages 119 & 120 are missing due to misnumbering. No material has been omitted.

CHAPTER 2

1. *a.* 25/32 *e.* 7/8
   b. 25/32 *f.* 1/2
   c. 4 3/16 *g.* 1 1/8
   d. 3 9/16 *h.* 3 5/16

2. The reading on the rule should be 6¼ inches from the center of the first hole to the center of the last hole.

3. *a.* 1 3/8
   b. 1 5/16
   c. 1 2/4 (1½)

4. *a.* 5/4
   b. 33/8
   c. 25/2

5. *a.* 1/2
   b. 3/8
   c. 3/4

6. 30 5/8 inches.

7. *a.* 1/4
   b. 4 3/8
   c. 3/16

8. *a.* 14 1/2
   b. 17 1/4
   c. 14 7/8

9. It is 2 5/8 inches from the center of the second hole to end *B.*

10. *a.* 0.250
    b. 0.1875
    c. 0.625

11. *a.* 3/16 = 0.1875 or one thousand eight hundred and seventy-five ten-thousandths.
    b. 7/32 = 0.21875 or twenty-one thousand eight hundred and seventy-five one-hundred thousandths.
    c. 15/16 = 0.9375 or nine thousand three hundred and seventy-five ten-thousandths.

12. The length of the collar would be 31.4160" long, less seam allowances.

13. *a.* 2 *d.* 4
    b. 5 *e.* 1
    c. 6 *f.* 3

14. $B = x \cdot C$

15. $B = x + C$

16. $C = \frac{x}{B}$

17. $C = \frac{2x}{B}$

18. Mensuration deals with the *measurement* of lines, angles, surfaces, and solids. Plane figures have *two* dimensions, and solid figures have *three* dimensions.

19. *a.* 10
    b. 1
    c. 5
    d. 4
    e. 3 or 2
    f. 9
    g. 2 or 3
    h. 8
    i. 6
    j. 7

20. 552¼ square inches.

21. 5 inches.

22. 92.4375 square inches.

23. $A = 84$ square inches.

24. Agree.

25. The broken lines in the rhomboid, rhombus, and trapezoid shown in figure 9 indicate the height or altitude.

26. Divide it with *diagonal* lines into simpler forms such as *triangles.* The *sum* of the various areas will be the total area of the figure.

27. *a.* 2.
    b. 4.
    c. 1.
    d. 3.

28. *Inside* the circle.

29. 4.59216 inches.

30. 101.82 square inches.

31. $C = \pi d$.

32. The diagonal is the same as the diameter of the circle. Therefore if the diagonal of the hexagon is 6¼ inches, the radius of the circle will be ½ of 6¼, or 3 1/8 inches.

33. Two formulas for determining the area of a circle are as follows: $A = \pi r^2$ and $A = d^2 \times 0.7854$.

34. The space inclosed by the three dimensions of a solid is referred to as volume. Volume is expressed in *cubic* inches, *cubic* feet, etc.

35. *a.* 8
b. 1
c. 4
d. 7
e. 6
f. 5
g. 2
h. 3

36. Agree.

37. 240.33 cubic feet.

38. $A = Ch$. When C is the circumference and h is the height.

39. Curved area of pyramid:
$A = \frac{1}{2} h_s \times C$
$A = \frac{1}{2} \times 30 \times 80$
$A = 15 \times 80$
$A = 1200$

area of pyramid base:
$A = S^2$
$A = 20 \times 20$
$A = 400$

Total area: 1200 + 400 = 1600 square inches.

40. $V = 1/3\ h \times A_b$

41. $A_s = 615.75$ square inches.

CHAPTER 3

1. Sixteenths of an inch.

2. Although the rule is graduated in sixteenths, the measurement appears to be halfway between 2 7/16 and 2½, which would be approximately 2 15/32 inches.

3. 19 inches.

4. Low–because the circumference rule would not be measuring the diameter but a chord that is shorter than the diameter.

5. Agree.

6. The readout measurement at the tape case will be 3' 4" X 16", which when added to the 2-inch case gives a total inside measurement of 3' 6" X 18".

7. The readout measurement will be 72 inches.

8. The center head can be used to scribe a line through the center of a circular object by marking or scribing two diameter lines. The two diameter lines will cross at the center of the circular object.

9. The square and miter head, center head, and turret protractor head. One use of the square and miter head is for checking a 45° angle; one use for the center head is to measure the diameter of a circle; and one use of the turret protractor is to transfer and lay out identical angles.

10. With the level on the body of the square, the roof line will pass the 12" mark on the body and the 3" mark on the tongue.

11. (Any three of the following are acceptable.) The framing square is used in sheet metalwork to make layouts, to check corners for squareness, to measure distances under 24 inches, to determine the pitch of a roof, and to find the opposite point on the circumference of a circle.

12. A framing square can be used to locate the center of a circle by locating two opposite points of the circumference as shown in figure 28 and drawing a diameter line. When this process is repeated at another location on the circumference, the two diameter lines will cross at the center of the circle.

13. Micrometers are precision measuring instruments that can measure distances smaller than the increments on a steel rule.

14. The stock being measured in figure 29 appears to be 1 23/32 inches in diameter.

15. Outside caliper.

16. The measurement will be too much.

17. Inside caliper.

18. To indicate thirty-one thousandths (0.031) of an inch, one mark to the right of zero (0) will be exposed on the barrel of the micrometer (0.000 + 0.025), and the thimble will have the sixth mark (0.006) even with the horizontal line on the barrel (0.025 + 0.006 = 0.031).

19. In figure 35, the reading indicated by view A is 0.150 inch; view B is 0.151 inch; view C is 0.160 inch; and view D is 0.175 inch.

20. To obtain a reading of 0.0179 inch with a vernier micrometer, the barrel scale reading will be 0.000 inch, the thimble scale reading will be 0.017 inch, and the vernier scale reading will be 0.0009 inch.

21. The readings of the vernier micrometer scales shown in figure 37 are as follows: view B is 0.1005 inch; view C is 0.1916 inch; and view D is 0.3999 inch.

22. The level shown in figure 38 contains six vials–two for horizontal *leveling* and four for vertical *plumb*.

23. The lower *horizontal leveling* vial is used to level the body of the framing square. The same results could be obtained by holding the level against the tongue of the square and reading either one of the lower *vertical plumb* vials.

24. 8 feet 9 inches.

25. Length 6 feet, width 3 feet 6 inches.

26. Because the pencil point is not as sharp as the metal points of dividers, and also because it makes a broader line or measurement mark.

27. Either can be used, since a hole is to be cut where the circles are marked or scribed.

28. To divide a line with points A and B at each end into two equal parts, the compass is used to form a radius greater than one-half of line AB, and then two arcs are drawn with A and B as the centers. Then a straight line is drawn through the two intersections of the arcs to divide line AB into two equal parts. This line is also perpendicular to line AB.

29. No. The procedure illustrated in figure 45 cannot be used to locate the center of a circle as shown in figure 48 because the perpendicular lines must also bisect chords AB and CD in order to cross at the center of the circle.

30. The compass is used to draw the circle and make the second diameter line perpendicular to the first diameter line.

31. The 90° angle of either triangle may be used to draw perpendicular lines.

32. 120°.

33. To draw a 40° angle to the right of a vertical line (90°), another line must be drawn from the index point on the protractor to the 130° mark on the outer scale.

34. A template held in place with clamps while the scriber is used will not slip and result in an erroneous shape or location of holes.

35. Yes. The template should have rivet hole locations, because it is a master pattern and is used to make duplicates of the original paper pattern.

36. The horizontal distance is 10 inches. The vertical distance is 3½ inches.

37. Yes.

38. Trammel points are sometimes called *beam compasses* because the adjustable points may be positioned along a rod or beam to *transfer* measurements or for laying out large *circles* and *arcs* in a manner similar to that used with dividers.

39. Trammel points and a circumference rule can be used to scribe a circle 110 inches in circumference by adjusting the trammel points to the 110-inch circumference calibration on the rule and scribing a circle with the setting which is approximately 35 inches in diameter.

40. The reference line established by a plumb line will be perpendicular to the horizon.

41. A level can be checked for vertical plumb by holding it parallel to a plumb line and observing if the bubbles rise to the center marks in the vertical plumb vials.

42. This can be quickly and easily accomplished by attaching a *plumb bob* to the chalk line.

CHAPTER 4

1. The vertical dimensions are shown on the elevation view, and the horizontal dimensions are shown on the plan view.

2. Figures 60, 61, 62, 63, and 64 contain orthographic projection views.

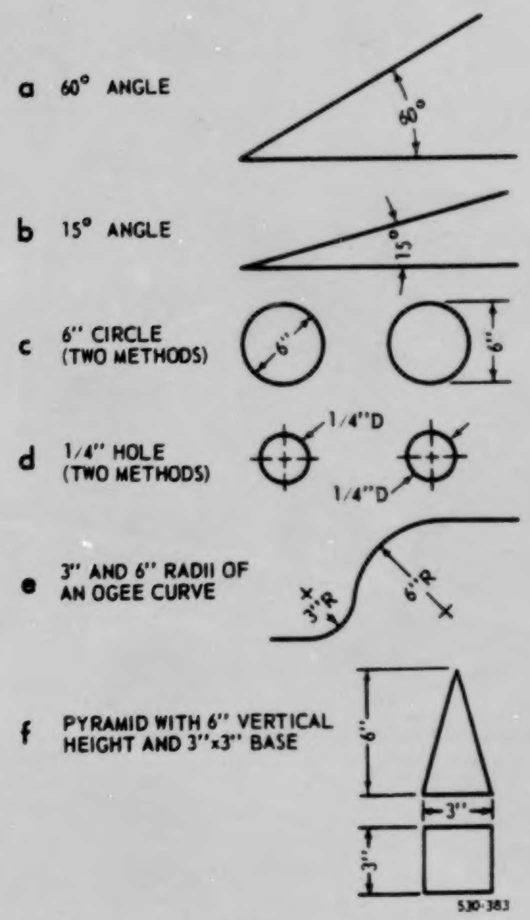
3. *a.* 2 1/8 inches.
   b. 1 inch.
   c. 1 3/8 inches.
   d. 7/8 inch.
   e. 1/2 inch.

4. 1¼" thick and 1½" wide.

5. The return duct under the floor is outlined with the hidden or dashed lines.

6. The heel radius is 6 inches.

7.


a 60° ANGLE
60°
b 15° ANGLE
15°
c 6" CIRCLE (TWO METHODS)
6"
6"
d 1/4" HOLE (TWO METHODS)
1/4"D
1/4"D
e 3" AND 6" RADII OF AN OGEE CURVE
3"R
6"R
f PYRAMID WITH 6" VERTICAL HEIGHT AND 3"x3" BASE
6"
3"
3"
530-383

CRE Figure 2. Answer for Review Exercise 7 Chapter 4

8. The duct is 12" wide and 20" high.

9. A supply duct symbol in a working drawing has two diagonal lines. A return duct symbol has one diagonal line.

10. Symbol for a supply section duct.

11. Turn vanes.

12. T & BR 20 X 12- EA. 700 cfm when used with a supply outlet symbol means top and bottom registers, each 20" wide by 12" high, and each with an airflow of 700 cubic feet per minute.

13. Each side of the corners is 1' 6", making a total length of 3'.

14. Copper and aluminum each have an expansion allowance of ¼ inch at each end, making a total of ½ inch.

15. *a.* Each end will have two 10' and one 7' 4" running sections.
    b. Forty-six expansion joints will be needed.

16. The inner flange extends 4 inches under the gravel and asphalt roof coating.

17. Figure 78 shows that the expansion joints are secured with four 1¾" aluminum flathead screws, however, in figure 79 you can see that additional fastening security comes from a continuous 1¾" strip of 0.051" aluminum alloy bent at 45° and fastened with 1" aluminum nails on 6" centers. This bent strip holds the bottom of the fascia along its length.

18. The general specifications indicate that the inner flange of the gravel stop and fascia must be fastened with nails spaced not over 3 inches on centers. The notes in figure 77 indicate that 1½" FHWS must be used at midpoint of each aluminum running section. This is not a discrepancy, because in figure 79 you can see that a 1½" X 1" 90° angle tar stop has been fastened to the edge of the roof with 2" aluminum nails on 6" centers.

CHAPTER 5

1. The length of the duct is missing from the working drawing.

2. The shape and measurements of the like component will be needed to draw a sketch and begin pattern development.

3. The height can be determined from the old roof jack or from the working drawing, and the triangulation layout method must be used to develop the pattern.

4. The shape of the component determines the layout method to be used.

5. The parallel line layout method should be used to develop the pattern of the elbow.

6. View A (elevation view) and view B (stretchout) of figure 82 both illustrate the element lines which are also the true length of the duct.

7. Incorrect transfer of element lines is the mistake; the compass probably slipped during the transfer.

8. The heel radius is 9", since the throat radius is 3" and the elbow is 6" in diameter.

9. The seam is located on the cheek of pieces II and IV, since the numbering started on the cheek in the pattern.

10. Two half gores and one whole gore are needed to make a 45° elbow. This can easily be seen in the elevation view of figure 86 by covering ½ of the 90° elbow with a piece of paper and counting the remaining gores.

11. Agree, because the element lines of piece III are parallel to the element lines of pieces I and IV.

12. The angle of the element lines must be 30° to return the branches parallel to the trunk.

13. Two half plan views are necessary for pattern development of any T-joint.

14. The *parallel* line method should be used to develop the pattern. The main pipe and *collar* are drawn to intersect at a 90° angle. The *plan* views are drawn and divided into equal spaces and the points projected to form the *element* lines until they intersect one another. Their point of intersection forms the miter lines which are used to develop the patterns for the *collar* and *cutout* by transferring the lengths to the stretchouts.

15. The length of the stretchout arc of a cone is determined by the circumference of the base of the cone.

16. Since the pattern was developed by the radial line method, the component must be a square tapered duct which is the truncated base of a right pyramid.

17. The mistake was made because of incorrect position of the plan view, as shown in view A of figure 94. The plan view should have been positioned as shown in view B of figure 94. Using the wrong position caused the slant height to be used instead of the true height, and thus caused the stretchout arc to be too short. Since this component is the lower part of a truncated right pyramid, the mistake caused the truncation line to be drawn closer to the base than it should have been.

18. No, the true height and slant height of a cone are identical. This can be easily seen in view B of figure 94 by assuming the broken line circle to be the base of a cone.

19*a*. In the elevation view, the centerline distance between the two truncation lines is 12 inches. The upper truncation line is 6 inches long.

b. The vertex point is established by projecting the two sides of the frustum until they intersect at the centerline.

c. The radius of the top truncation line on the pattern is determined by the distance from the vertex to either end of the top truncation line on the elevation view. (This can also be seen in figure 98 of the text.)

d. By horizontal projection of the points of intersection (element lines and lower truncation line) to the shortest outside element line.

e. The stretchout arc should be approximately 31½ inches long.

20. Element lines 1, 7, and 1 are equal; lines 4 and 10 are equal; lines 2, 6, 8, and 12 are equal; and lines 3, 5, 9, and 11 are equal. They have the same intersecting points, as can be seen in the elevation view of figure 100 where the horizontal projection lines intersect the gutter radius.

21. The mistake was made because the stretchout arc was made too long as a result of incorrect compass setting or slippage.

22. Disagree. The element lines in triangulation layout are sloping lines. The true length lines are obtained from the true length chart.

23. The horizontal distance for points 4 and 10 in the true length chart was made too long.

24. The framing square can be used to check angles AG10 and DH4 for squareness. If these angles are not each 90°, the pattern is not accurate.

25. When the two right triangles in the half pattern shown in figure 106 are joined, they will form an isosceles trangle. This is true because lines AG and DH are equal and lines A-10 and D-4 are equal (see plan view in figure 110).

26. Four isosceles trangles will be formed.

27. A whole plan view will be needed, since the cone is not symmetrical. The same procedures used to develop the true length chart and pattern in figures 107 and 108 can be used; the only difference is that a half pattern will be required for each half of the whole plan view, since the cone is offset in two directions.

28. Seam allowances and additions are made on patterns so that the component can be joined or extended.

29. Seam allowances are determined by the amount of material required to form the seams. Allowances for additions are determined by the amount of material to make a connection for fill in a gap.

30. The element lines, seam lines, and points are marked on the metal for references when forming the component and to eliminate error.

31. A pencil is used to mark around the edges of paper patterns instead of a scribe because the scribe will fray the edges of the pattern and cause an inaccurate transfer.

32. No, because the pattern of the oblique cone is already a whole pattern.

CHAPTER 6

1. Copper, because copper had a much higher heat resistance, is ductile, and can be annealed easily.

2. Toughness and hardness are missing from the punch. Toughness allows the metal to withstand forces slowly or suddenly, and hardness allows the metal to be solid or firm.

3. The head mushroomed easily; therefore, the chisel has lost its *toughness* and *hardness* properties. The head is examined and you notice that the mushroomed edges are breaking away from the chisel; therefore, the head has become *brittle.*

4. Toughness and hardness are missing from the chisel, since both allow a metal to withstand force.

5. If the metal springs back to its natural shape it has good *elastic* properties, and if it bends easily it has good *ductile* properties. Examination of the metal that sprang back to its natural shape reveals that its surface is highly polished and shiny. The metal you tested is *stainless* steel. If the piece of metal had bent easily and had a reddish brown color, it would have been *copper.*

6. Black iron would be used, since it is easily formed, has a high melting point, and the door is located inside.

7. Since the box will be painted and stored inside, black iron can be used. Black iron has good forming qualities and is used often for fabricating storage boxes.

8. Galvanized iron would be selected for the fabrication. It has good forming qualities and will resist corrosion from the condensation of refrigerated air.

9. Galvanized iron would be suitable, since it has good forming qualities and resistance to corrosion.

10. Tin plate would be a suitable substitute, since it has some corrosion resistance and is the same base metal as galvanized iron.

11. The old metal is tin plate, which has corrosion resistance and is often substituted for galvanized iron.

12. Stainless steel has better corrosion resistance because it has chromium and nickel alloyed in it.

13. Stainless steel grade 18-8 type 304L and finish No.7. Because stainless steel is corrosion resistant, No.7 is a highly polished finish, and the second variation has the carbon lowered to reduce corrosion to a maximum during welding.

14. The 1100–H14 aluminum would be best suited, since it is light in weight, can be formed easily, and has a tensile strength of 17,500 psi.

15. The 1100–H16 aluminum would be best suited, since it is strong and has good working qualities.

16. Copper, because copper is highly resistant to corrosion and is easily soldered.

17. Disagree. Lead is very heavy and has a much lower melting point than galvanized iron and would not make a good cover for a fire door.

18. Lead, because of its resistance to chemicals and its forming qualities.

19. Disagree. Zinc is corrosion resistant but not chemical resistant. Stainless steel would be the metal to select because of its high resistance to chemicals.

20. Scraps of galvanized iron can be used to cut the acid, since the iron is coated with zinc.

21. The metal would be annealed to soften it by heating it to a cherry red color and quenching in water. The reddish-brown color indicates that the metal is copper, and copper is annealed as described above.

22. The likely mistake is the metal did not reach a cherry red color to remove the hardness.

23. Temper is being restored to the point.

24. The likely mistake is that the surface wasn't cleaned, resulting in an inaccurate color appearance on the surface.

STOP— **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 PENCIL.**

53350 01 22

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

132

Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. The form number of this VRE must match

   a. the form number on the answer sheet.
   b. the number of the Shipping List.
   c. my course number.
   d. my course volume number.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a

   a. pen with blue ink.
   b. number 1 black lead pencil.
   c. ball point or liquid-lead pen.
   d. pen with black ink.

3. If I tape, staple or mutilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet,

   a. I will receive a new answer sheet.
   b. my answer sheet will be hand-graded.
   c. my answer sheet will be unscored or scored incorrectly.
   d. I will be required to retake the VRE.

Chapter 1

4. (100) TOP SECRET material should be transmitted only by

   a. mail.
   b. registered letter.
   c. authorized officers or key civilians.
   d. by monitered telegraph.

5. (100) SECRET information should only be given to personnel with

   a. a SECRET clearance.
   b. a knowledge of AFR 205-1.
   c. a SECRET clearance and the right and need to know.
   d. the right and need to know.

6. (100) The discussion of classified information is

   a. permitted on monitered calls.
   b. always prohibited over the telephone.
   c. permitted on class "A" telephones.
   d. permitted on restricted AUTOVON calls.

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7. (100) Which Air Force regulation sets the policy pertaining to discussion of classified information on the telephone?

   a. AFR 205–1.
   b. AFR 205–3.
   c. AFR 205–5.
   d. AFR 205–7.

8. (100) Which of the following jobs are included in the specialty description for sheet metalworkers?

   a. Sets up job by tack welding and use of various jigs, clamps, and fixtures.
   b. Cuts, trims, forms, shapes, rivets, and solders patches.
   c. Determines need and arranges for heat-treating in connection with forming operations.
   d. Assembles machinings, castings, and forgings, and fastens them with screws, bolts, or rivets.

9. (101) A duct repair job requires replacement of an offset. Which manual should you use for assistance in laying out the offset?

   a. AFM 85–2, *Preventive Maintenance.*
   b. AFM 85–4, *Maintenance and Construction Methods for Buildings and Structures.*
   c. AFM 85–1, *Resources and Work Force Management.*
   d. Technical Manual 40H–1–1, *Heating, Ventilating, and Sheet Metalwork.*

10. (102) If the Federal stock number of a hand riveting hammer is 5120–224–4113, which of the following statements is true?

    a. The first four numbers identify the FSC group and class.
    b. The first four numbers identify the group.
    c. The first four numbers identify the class index.
    d. The first four numbers identify the FIIN.

11. (102) Which of the following procedures should be used when researching stock numbers by item name?

    a. Determine the group class by using cross-reference index S–00–1–1 and look in the alphabetical listing of the DOD Federal Supply Catalog for that group class to identify the item and identifying number.

    b. Determine the group class by using alphabetical index H2–3 and look in the alphabetical listing of the DOD Federal Supply Catalog for that group class to identify the item and identifying number.

    c. Determine the group class by using cross-reference index S–00–1–2 and look in the alphabetical listing of the DOD Federal Supply Catalog for that group class to indentify the item and identifying number.

    d. Determine the group class by using numeric index H2–1 and look in the GSA catalog to identify the item and identifying number.

12. (102) If you are to order replacement cutting blades for a ring and circle shear and the technical order lists the part number only, which of the following indexes should you use to find a stock number?

    a. Cross-reference index S–00–1–1.
    b. Alphabetic index H2–3.
    c. Cross-reference index S–00–1–3.
    d. Numeric index H2–2.

13. (102) Which of the following is an authority for requesting shop equipment?

a. The stocklist.
b. The DOD catalog.
c. The organizational allowance.
d. The table of allowances.

14. (103) Which of the following statements pertains to Air Force Form 327?

a. It authorizes approved work in the civil engineer group.
b. It authorizes all work in the civil engineer group.
c. It authorizes minor maintenance and service calls.
d. It authorizes service calls.

15. (103) Which of the following forms is used to coordinate all work scheduling in the civil engineer shops?

a. Air Force Form 327.
b. Air Force Form 332.
c. Air Force Form 561.
d. Air Force Form 1451.

16. (103) Which of the following forms will you use for man-hour reporting?

a. Air Force Form 327.
b. Air Force Form 561.
c. Air Force Form 660.
d. Air Force Form 1445.

17. (103) Which of the following forms are used to request issue of a bar folder and a replacement blade for a bandsaw?

a. Air Force Form 561 and DD Form 1150.
b. Air Force Form 601b and DD Form 1150.
c. Air Force Form 601b and Air Force Form 561.
d. Air Force Form 601b and Air Force Form 1150.

18. (103) Which of the following forms is used to identify a piece of equipment that is *not* reparable?

a. DD Form 1574.
b. DD Form 1574-1.
c. DD Form 1577-2.
d. DD Form 1577.

Chapter 2

19. (104) In figure 4 of the text, the distance between points 1 and 3 on the graduated scale is

a. 1 3/8 inches.
b. 1 5/8 inches.
c. 1 5/16 inches.
d. 1 9/16 inches.

20. (104) In figure 4 of the text, the distance between points *c* and 7 on the graduated scale is

a. 2 3/16 inches.
b. 2 14/32 inches.
c. 2 11/16 inches.
d. 4½ inches.

21. (104) In figure 4 of the text, the distance between points 2 and 4 on the graduated scale is

a. 1 13/32 inches.
c. 1¾ inches.
b. 1½ inches.
d. 2 3/16 inches.

22. (104) In figure 4 of the text, the distance between points 5 and *g* on the graduated scale is

a. 2 5/8 inches.
c. 3 5/16 inches.
b. 3 inches.
d. 3 13/16 inches.

23. (104) A piece of sheet metal has 8 holes drilled along a straight line, and each hole is spaced 5 3/16 inches apart (center to center). The distance between the centers of the end holes is

a. 35 inches.
c. 41½ inches.
b. 36 5/16 inches.
d. 46¼ inches.

24. (104) If 2 3/4 feet and 3 1/8 feet have been cut from an 8-foot sheet of metal, the length of the remaining piece is

a. 2 1/8 feet.
c. 3 1/8 feet.
b. 2¼ feet.
d. 3¼ feet.

25. (104) A number 42 twist drill makes a hole nine thousand three hundred and seventy-five hundred thousandths of an inch. Use the decimal equivalent chart shown in figure 5 of the text and determine which of the following fractions has the same value.

a. 5/64.
c. 59/64.
b. 6/64.
d. 30/32.

26. (104) Which of the following equations has a mistake in the transposition?

a. $B = X + C$
$X = B - C$

c. $B = XC$
$C = \frac{B}{X}$

b. $C = B - X$
$B = C + X$

d. $C = \frac{BX}{2}$
$B = \frac{2X}{C}$

27. (105) In figure 7 of the text, what is the area of triangle DAC if line DB is 6 inches and line AB is 9 inches?

a. 7½ square inches.
c. 54 square inches.
b. 27 square inches.
d. 108 square inches.

28. (105) If the outside dimensions of a toolbox, including the lid, are 24 inches long, 12 inches high, and 10 inches wide, the total outside area of the box is

a. 460 square inches.
c. 1296 square inches.
b. 816 square inches.
d. 2880 square inches.

29. (105) The area of a trapezoid 5 inches high with parallel sides 13 inches and 17 inches in length is

a. 65 square inches.
b. 75 square inches.
c. 85 square inches.
d. 552½ square inches.

30. (105) With the following information about the trapezium shown in figure 9 of the text, what is its area? The upper left triangle has a height of 4 inches and an area of 6 square inches. The upper right triangle has a base 4 inches and an area of 24 square inches. The lower left triangle has a height of 6 inches and an area of 18 square inches. The lower right triangle has a height of 9 inches and an area of 27 square inches.

a. 75 square inches.
b. 81 square inches.
c. 99 square inches.
d. 102 square inches.

31. (105) If the diagonal of the polygon shown in figure 11 of the text is 7 inches, the area is

a. 18.1869 square inches.
b. 28.9216 square inches.
c. 31.8267 square inches.
d. 127.3069 square inches.

32. (105) The circumference of a circle that has a radius of 3½ inches is

a. 7.736 inches.
b. 10.9956 inches.
c. 21.9912 inches.
d. 35.343 inches.

33. (105) The area of a circle that has a diameter of 8 inches is

a. 6.5777 square inches.
b. 18.242 square inches.
c. 50.2656 square inches.
d. 64.1406 square inches.

34. (105) The volume of a drip pan that measures 3 feet long, 2 feet wide, and 3 inches deep is

a. 1½ cubic feet.
b. 2 cubic feet.
c. 3 cubic feet.
d. 18 cubic inches.

35. (105) The total outside surface area (sides and both ends) of a circular tank 10 feet tall and 5 feet in diameter is

a. 157.08 square feet.
b. 172.788 square feet.
c. 176.715 square feet.
d. 196.35 square feet.

36. (105) What is the volume of a sphere that has a diameter of 3 inches?

a. 4.7124.
b. 9.4338.
c. 14.1372.
d. 16.1372.

37. (106) Using the circumference rule illustrated in figure 20 of the text, the length and width (not including seams) of a piece of sheet metal which can be formed into a round duct 2 feet long and 7¼ inches in diameter is

a. 7¼" X 23".
b. 23" X 24".
c. 23" X 24".
d. 24" X 24".

38. (106) A piece of sheet metal is measured with an 8-foot power-return steel tape using the 1/16-inch hook to hold the end of the tape. The length and width of the piece of sheet metal when the visible readouts on the tape are 35 3/8 and 25 5/8 inches, respectively, is

a. 35 4/16 inches long and 25 6/16 inches wide.
b. 35 5/16 inches long and 25 9/16 inches wide.
c. 35 3/8 inches long and 25 5/8 inches wide.
d. 35 7/16 inches long and 25 11/16 inches wide.

39. (106) A 2" X 2" square hole is to be made in a 6" X 6" square sheet of metal. Which of the following components of a combination set would be the best to lay out the inner square if its corners are to point to the midpoint of each side of the outer square?

a. A blade and center head.
b. A combination square.
c. A scriber and spirit level.
d. A blade and turret protractor.

40. (106) Suppose that a framing square and a level have been used to determine that a roof has a 5–12 pitch as shown in figure 27 of the text, but because of an error in fabrication, the pitch of the roof jack is 6–12. If the roof jack is installed anyway, which way will it tilt if the roof slopes up on the north side of the point of installation?

a. East.
b. West.
c. South.
d. North.

41. (107) The sheet metal specialist would most likely use calipers for measuring

a. angles.
b. beveled edges.
c. diameters and distances.
d. the curvature of arcs.

42. (107) The two main types of micrometers are

a. plain and vernier.
b. inside and outside.
c. plain and outside.
d. vernier and inside.

43. (107) All of the following are principal parts of a micrometer *except* the

a. frame.
b. barrel.
c. hammer.
d. anvil.

44. (108) Layout tools used primarily in the shop are the

a. architect's scale, triangle, and caliper.
b. divider, T-square, and pencil compass.
c. steel rule, T-square, and divider.
d. framing square, pencil compass, and hermaphrodite caliper.

45. (108) Using figure 40 of the text, the actual length of a section of heating duct which is drawn to quarter scale and measures 8 to the left of zero and to the 9th increment to the right of zero is

a. 2' 3".
b. 8' ¾".
c. 8' 9".
d. 84¾".

46. (108) What reduction scale (on an architect's scale is used on a working drawing which has a circle 9 inches in diameter that represents a tank bottom 3 feet in diameter?

a. ½" = 1'.
b. 1" = 1'.
c. 1½" = 1'.
d. 3" = 1'.

47. (108) If the ogee curves and parallel lines shown in figure 49 of the text represent one side of an offset section of a duct and it is desired to use a pencil, straight edge, and pencil compass to draw the other side parallel to lines AB and CE and arcs BE and EC of figure 49, which of the processes illustrated in the graphic solutions shown in figures 44 through 48 of the text would be used?

a. Processes in figures 44 and 48.
b. Processes in figures 46 and 44.
c. Processes in figures 46 and 45.
d. Processes in figures 44 and 45.

48. (108) In figure 48 of the text, if chord CD is moved so that points B and C occupy the same location, where, if at all, will the perpendicular to chord CD pass through the perpendicular to chord AB?

a. At the same place.
b. Closer to chord AB.
c. Farther from chord AB.
d. It will miss the other perpendicular altogether.

49. (108) A working drawing shows the side view of a cone-shaped vent cap such as is used to keep rain from entering a vent pipe. The drawing of the vent cap is measured with a protractor such as shown in figure 55 of the text. The index point of the protractor is placed at the vertex of the cone, one side of the cone is under the 0° mark on the inner scale, and the other side of the cone is under the 40° mark on the outer scale. What is the vertex angle of the vent cap?

a. 40°.
b. 100°.
c. 140°.
d. 180°.

50. (108) The size of a template should be

a. three-eights scale.
b. quarter scale.
c. half scale.
d. full scale.

51. (108) Which of the following layout tools does *not* need a T-square as a base line when a pattern is being made on a drawing board?

a. A 30°–60° triangle.
b. A protractor.
c. A 45° triangle.
d. An irregular curve.

52. (108) If a duct offset is being built and the ogee curves in the top and bottom sides have a radius of 27 inches, the layout tool that would be most suitable to draw the arcs is

a. a pencil compass.
b. trammel points.
c. wing dividers.
d. an irregular curve.

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53. (108) You are installing a gas heater vent stack through a roof. The layout tool that would be best suited to locate the center of the hole to be cut in the roof so that it will be directly over the center of the vent outlet of the heater is

a. a plumb line.
c. a chalk line.
b. dividers.
d. a level.

Chapter 4

54. (109) Assume that you are installing a heating system which is similar to the systems illustrated in figures 62, 63, and 64 of the text. Which of the following statements is correct?

a. The working drawing will include a view like figure 65.
b. The working drawing will include a view like figure 66.
c. The working drawing will include a view like figure 67.
d. The working drawing will include views like figures 62, 63, and 64.

55. (110) What are the outside length and width dimensions of the building illustrated in figure 62 of the text if the inside walls are 5 inches thick and the outside walls 6 inches thick?

a. 21' 5" long by 18' wide.
c. 26' 10" long by 19' wide.
b. 21' 6" long by 19' wide.
d. 31' 10" long by 19' wide.

56. (111) The component that is installed at the supply opening of a rectangular duct if the symbol on the working drawing is a rectangle with two diagonal lines is a

a. damper.
c. register.
b. screen.
d. louver.

57. (111) Where is the damper symbol shown in *d* of figure 74 of the text used in a working drawing?

a. In the plan view.
c. In the pictorial view.
b. In the detail view.
d. In the elevation view.

58. (112) The construction of the inside and outside corners of the gravel stop and fascia shown in figure 77 of the text is

a. lapped corner joints.
b. mitered and welded corner joints.
c. riveted corner joints.
d. soldered corner joints.

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59. (113) Which of the following duct measurements indicates that the triangulation layout method is to be used to develop the pattern?

    a. 10" diameter to 6" diameter.
    b. 12" X 16" to 10" diameter.
    c. 12" X 16" to 12" X 16".
    d. 12" X 12" X 12' long.

60. (113) Flat pattern layouts for rectangular, round, and square ducts are developed by using the

    a. Y-branch method.
    b. triangulation method.
    c. radial line method.
    d. parallel line method.

61. (113) When developing a pattern for a T-joint, how many elevation and plan views are necessary to locate the miter lines?

    a. One plan and one elevation view.
    b. One elevation and two plan views.
    c. One plan and two elevation views.
    d. Two plan and two elevation views.

62. (113) An assembled 90° elbow is found to measure only 85°. If the mistake was made when the elevation view was drawn, the probable mistake is an *incorrect*

    a. dividing of the heel arc.
    b. number of gores used during assembly.
    c. seam allowance.
    d. heel radius.

63. (114) Which steps are the same when developing a pattern for an elbow using the parallel line layout method and developing the pattern for a funnel using the radial line layout method?

    a. Finding the vertex.
    b. Shaping the pattern.
    c. Finding the pattern stretchout length.
    d. Dividing the miter lines.

64. (114) The true elevation view of a pyramid with a square base appears to be larger because

    a. it shows the slant height.
    b. it shows the vertical height.
    c. it shows the front elevation view.
    d. of the position of the plan view.

65. (114) A plan view on a working drawing requires a component 30" long to be reduced from 20" X 20" to 10" to 10". If after developing the pattern and fabricating the component you find it to be too short, where was the mistake made?

    a. The diagonal of the plan view is parallel to the base of the pyramid.
    b. An incorrect length of the stretchout arc.
    c. An incorrect position of the plan view.
    d. The T-square slipped while transferring the element lines from the elevation view to the pattern stretchout.

66. (114) During radial line pattern development of an irregular frustum, why are the intersecting points of the truncation and element lines projected to the true height line in the elevation view?

a. To avoid confusion.
b. To locate the points on the half plan.
c. So that the same pattern can be used to develop a regular frustum.
d. So that the true lengths of the element lines can be determined.

67. (115) The most important step in finding the true length of the element lines in the triangulation layout method is

a. the numbering sequence of the element lines.
b. lettering and numbering the plan and elevation views.
c. transferring the lengths of the element lines from the plan view to the true length chart.
d. transferring the lengths of the element lines from the elevation view to the true length chart.

68. (115) Assume that element lines 2, 6, 8, and 12 on the pattern for a round tapered downspout such as shown in figure 100 of the text are too long. When the metal pattern is fabricated, it will cause points 2, 6, 8, and 12 to contact the gutter radius before the other points. What is the likely mistake?

a. The vertex is off center.
b. An incorrect cutout on the gutter.
c. An incorrect divider setting.
d. The radius of the gutter is too small.

69. (115) Before the pattern shown in figure 111 of the text is cutout and transferred to metal, what would be the results when a square is used to check the pattern for accuracy?

C

a. Line H–4 in the pattern should be equal the vertical height.
b. Line H–4 should be the same length as line G–10.
c. Angles AG10 and DH4 should each be 90°.
d. Angles HD2 and GA12 should each be 90°.

70. (116) When transferring a pattern to metal for several duplicate conponents, a template is more desirable than paper patterns because

a. continued use of a paper pattern will reduce accuracy.
b. paper patterns can be used only one time.
c. seam allowances are not needed when using a template.
d. the template will save time, since one less part will be needed.

71. (116) A whole pattern for an elbow is transferred to make half gores by

a. marking the whole pattern and cutting it in half.
b. working off the center line and marking half the pattern.
c. making a whole pattern and cutting off one miter line.
d. reversing the pattern on the metal for each half gore.

72. (117) The louvered metal cover on a steam radiator is to be replaced and painted. Which of the following metals would be best suited for the cover?

a. Galvanized iron.
b. Stainless steel.
c. Black iron.
d. Copper.

73. (117) The ducts for a combination heating and air-conditioning unit are to be fabricated using corrosive-resistant metal, and the fabrication and locking methods for the components require the metal to form easily. The metal that should be selected for the fabrication is

a. zinc.
b. tin plate.
c. galvanized iron.
d. black iron.

74. (117) Which of the following metals has the same forming qualities and can be substituted for galvanized iron when fabricating gutters?

a. Zinc.
b. Copper.
c. Black iron.
d. Tin plate.

75. (118) A permanent building is to have gutters installed that are easily sealed and have maximum corrosion resistance and minimum maintenance. Which of the following metals would be best suited to meet these requirements?

a. Galvanized iron.
b. Aluminum.
c. Zinc.
d. Copper.

76. (118) A section of an awning being replaced is light in weight, has a tensile strength of approximately 15,000 psi, and is ductile; the unpainted surface is shiny. The metal that you should use to replace the section is

a. galvanized iron.
b. 1100–H14 aluminum.
c. 1100–H16 aluminum.
d. 1100–H18 aluminum.

77. (118) A nonferrous metal used to coat black iron and cut soldering flux is

a. zinc.
b. lead.
c. aluminum.
d. copper.

78. (118) The most likely mistake made in the tempering process, if the cutting edge of a cold chisel is too soft, is that the

a. temperature reached during the process was too high.
b. temperature of the chisel was allowed to reach 540° F.
c. chisel was cleaned with a piece of abrasive cloth.
d. chisel was dipped in oil for protection during firing.

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CDC 53350

SHEET METAL SPECIALIST

(AFSCs 53330 and 53350)

Volume 2

Sheet Metalworking Hardware, Tools, and Equipment

13-1

Extension Course Institute
Air University

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PREPARED BY AMARILLO AIR FORCE BASE, TEXAS, AIR TRAINING COMMAND

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE BASE, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

THIS SECOND volume of your career development course concerns the hardware, tools, and equipment you will use in sheet metalwork. You will learn what devices are used to fasten sheet metal such as rivets, bolts, screws, clips, and braces. You will also learn about the tools and equipment used for such sheet metalworking operations as cutting, drilling, folding, forming, soldering, and spot welding.

The subjects in this volume are specified for upgrade training of sheet metalworkers by your specialty description in Air Force Manual 39–1 and by your specialty training standard.

The number which appears on the figures in this volume (for example, 530–845) represents the preparing agency's illustration file number.

Questions relative to the purely technical subject matter content of this text, specifically any questions concerning the accuracy or currency of factual information, plus comments and recommendations for improvement or correction therof, should be forwarded to Technical Training Center, (TSOC), Chanute AFB, Illinois 61868. All questions concerning your enrollment, the administration of your course, or any of ECI's autoinstructional devices (Your Key to Career Development, the Chapter Review Exercise, Volume Review Exercise, Course Study Reference Guide, or Course Examination) should first be taken up with your education or training officer or NCO as appropriate. If he can't answer your question, then the question should be forwarded to ECI, Gunter AFB, Alabama 36114, preferably on ECI Form 17 (Student Request for Assistance).

This volume is valued at 18 hours (6 points).

Material in this volume is technically accurate, adequate, and current as of May ~~1970~~. 1975

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CHAPTER 1

Fastening Hardware and Devices for Sheet Metal

IN THIS CHAPTER we will discuss fastening hardware and devices which you will use to fabricate and install various sheet metal components in permanent and semipermanent installations. These fasteners are selected and used to assemble and secure components in the most suitable way possible. Although seams, spot welds, and soldered joints are often used to fasten sheet metal sections together, many items are fastened with rivets, screws, bolts, nails, cleats, clips, hangers, or braces. When blueprints, drawings, or specifications are furnished, you must identify the fasteners and sizes specified. On the other hand, if not furnished, you must determine which fastener or fastening method should be used for the purposes indicated in general specifications and guidelines.

2. The method used for fastening a particular job is usually determined by the thickness and kind of material used, size and shape of the job, and materials and equipment available. However, in some cases a combination of fasteners or fastening methods is necessary.

1. Fastening Sheet Metal with Rivets

1-1. Rivets are used considerably in sheet metalwork and are satisfactory for fastening sheet metal from both the standpoint of strength and neatness if properly used. Riveting can be done by hand or by machine; however, in the type of work you do, most riveting is done by hand.

1-2. Rivets vary in the following respects: the kind of metal from which they are made, type of head, diameter, and length. Figure 1 illustrates some of the various shapes of rivet heads you may encounter. The rivet most often used in the sheet metal shop is the tinner's rivet; however, you may also use Monel rivets and aluminum rivets.

1-3. **Tinner's Rivets.** As a sheet metalworker you use tinner's rivets more than any other type. They are made of mild (soft) steel, are easily formed with a hand riveting set, and are usually tinned. The tinner's rivet illustrated in figure 1 is available in various diameters and lengths. The rivet sizes are identified according to the weight per thousand. For example, 1,000 of the smallest tinner's rivets (which are identified as 8-ounce rivets) weigh 8 ounces. Tinner's rivets are available in the following sizes: 8 oz, 10 oz, 1 lb, 1¼ lb, 1½ lb, 1¾ lb, 2 lb, 2½ lb, 3 lb, 3½ lb, 4 lb, 5 lb, 6 lb, 7 lb, 8 lb, 10 lb, and 12 lb. You can see there are many sizes available; however, in the sheet metal shop, the sizes in the following list are used more than the others:

Size of Rivet	*Diameter of Shank*	*Length*	*Gage of Sheets Being Joined*
1 lb	0.109"	3/16"	26
2 lb	0.148"	9/32"	24
2½ lb	0.1607"	5/16"	22
3 lb	0.165"	21/64"	20
4 lb	0.176"	11/32"	16

1-4. **Monel Rivets.** Monel rivets like other rivets vary in diameter, length, and head shape. These rivets are harder to drive than tinner's rivets because of the hardness of the metal. In sheet metalwork you use Monel rivets when manufacturing or repairing parts and components such as stainless steel trays, pans, hoods, and serving equipment in dining facilities.

1-5. **Aluminum Rivets.** There are many types and shapes of aluminum rivets available; however, the aluminum sheets you will most likely be riveting will be soft aluminum and will require soft aluminum rivets. Two general-purpose aluminum rivets, identified as the 1100–F and 3003,

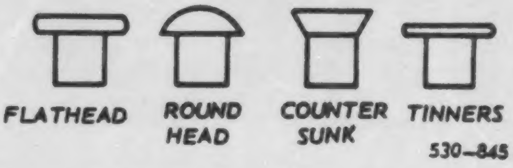


Figure 1. Typical rivet heads.

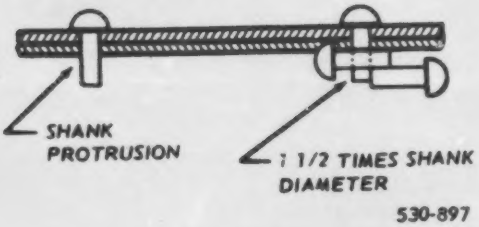


Figure 2. Proper rivet length.

are recommended for use on nonstructural parts fabricated from soft aluminum. The 1100–F and 3003 are available with flat countersunk round, or universal heads. The main advantage of these rivets in the sheet metal shop is that they can be used without further treatment and are easily driven with a handset.

1-6. **Design of Riveted Joints.** Riveted joints are of two general types—lap joints and butt joints. The lap joint is made by placing the sheets of metal so that one sheet will overlap the other. The butt joint is made by butting the plate or sheet ends together and using one or more cover plates. Both types of joints can be single riveted, double riveted, or triple riveted, depending upon whether one, two, or three rows of rivets are used. If more than one row of rivets is used and the rivets are directly behind each other, they are said to be chain riveted. If they are diagonally behind each other they are stagger riveted. Chain or stagger riveting can be used both in lap and in butt joints when more than one row of rivets is used.

1-7. Rivet spacing for the joint can be obtained from the drawing or blueprint. If the spacing is not specified, the type of seam will serve as a guide in determining whether the rivets are spaced close together or far apart. For instance, a joint that must be liquidtight has many more rivets per inch than a joint that need not be liquidtight. Whatever the rivet spacing, the center of the rivet hole is located twice the diameter of the rivet head from the edge of the sheet (some sheet metalworkers prefer to use two and one-half times the shank diameter). The number of rows of rivets used in making a joint will depend on the amount of strength needed in the joint. The distance between the rows of rivets is known as *the transverse pitch,* and the distance between the rivets in the same row is called *the rivet pitch.*

1-8. **Determining Size of Rivet To Be Used.** The diameter of the rivet is usually determined by the thickness of the plate or sheet stock from which the part is made. Unless otherwise specified, the diameter of the rivet shank is approximately three times the thickness of the sheet metal. The length of the rivet shank is determined by the combined thickness of the sheets to be fastened. The shank should protrude through the metal sheets, as shown in figure 2, about one and one-half times the diameter of the rivet to permit the forming of a good shaped head and for maximum holding strength.

1-9. **Making a Rivet Hole.** After the rivet size is determined and the layout completed, the center of the hole is marked. This is done by placing a sharp pointed punch on the center and striking it lightly with a hammer, then completing the operation of making the hole by using a drill or punch. The hole should be slightly larger than the rivet. If the location of the holes is near the edge of the sheet, the Whitney hand punch (shown in fig. 53) can be used for piercing the holes; if the location of the holes is not near the edge of the metal, a hand drill or power drill may be used for piercing the holes. Whichever way you make the holes, remember that the edges of the holes must be smooth and the hole slightly larger than the rivet.

1-10. When several sheets are to be drilled or punched, a template is used to locate the holes. On individual sheets, you can use a pencil, compass, scriber, or dividers. However, you should not use a scriber on aluminum or stainless steel, because this will scratch the metal and may cause aluminum to crack when being formed. A soft, pointed pencil is recommended for marking aluminum and stainless steel.

1-11. Before driving rivets remove any burrs and chips to prevent marring the metal. This also permits the sheets to seat tightly against each other. Burrs can be removed by inserting the point of a larger sized twist drill in the hole and turning it. A countersink such as shown in figure 49 may be used in the same manner.

1-12. To insure proper alignment of rivet holes, the sheets must be held in proper relation to each other while the rivets are being inserted. A holding device, called a Cleco, is the tool to use for this job. A Cleco in every third or fourth

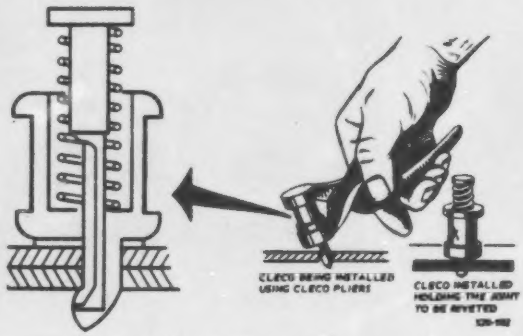

CLECO BEING INSTALLED USING CLECO PLIERS
CLECO INSTALLED HOLDING THE JOINT TO BE RIVETED

Figure 3. Cleco installation.

hole along the seam is usually sufficient. Figure 3 shows how the Cleco is used.

1-13. **Setting, Upsetting, and Heading Rivets.** Rivets are usually installed by placing the manufactured head against a solid surface, such as a backing plate, and following the steps shown in figures 4, 5, and 6. This procedure is used when setting rivets with a hand riveting set. The steps illustrated are necessary to insure a strong rivet with a proper head and to prevent the joint from being distorted.

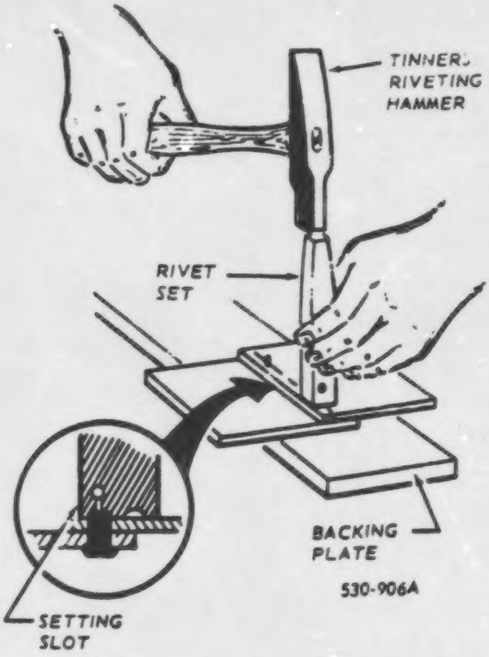


Figure 4. Setting rivets.

1-14. If the setting step, illustrated in figure 4, is not performed correctly, the sheets may not seat tightly against each other, which may cause the rivet to swell between the sheets during the upsetting step. This will make the rivet too short to form a proper head, cause the metal around the hole to dimple (bulge), and fail to form a strong joint.

1-15. Upsetting the rivet, as shown in figure 5, is also very important, since it is the beginning of the heading process. If the rivet is struck too hard, the rivet shank will be flattened too much to form a good head during the heading step.

1-16. The heading step, illustrated in figure 6, uses the head forming depression of the rivet set to form a strong well-shaped head. Heading the rivet enlarges the head to provide a holding surface all around the hole.

1-17. The tools needed for hand riveting are a riveting hammer, a rivet set, and a backing surface, such as a backing plate, hand dolly, or bench stake. Refer to figures 4, 7b and 7c for illustrations of these backing surfaces. Rivet sets $\frac{3}{16}$ inch in diameter and under are available in most sheet metalworker toolkits. A rivet set is required to form a good shaped head on the rivet. The size of the set depends upon the size of the rivet. The shape and size of the backing plate, hand dolly, or bench stake depend on the size of the rivet, thickness and size of the material, location, and conditions under which the driving is taking place. Therefore, many shapes and sizes of hand dollies and bench stakes are available in most sheet metal shops. A piece of square, cold-rolled steel bar of the proper weight can be used as a backing plate when no interference exists. Where riveting is not so simple, hand dollies or

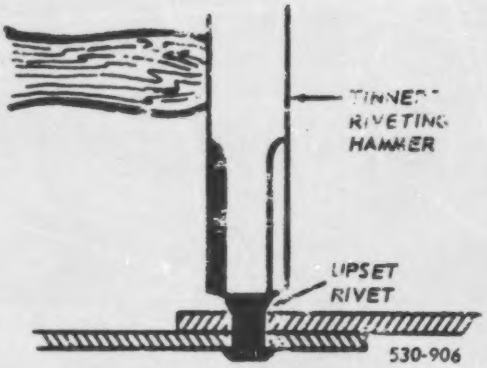


Figure 5. Upsetting rivets.

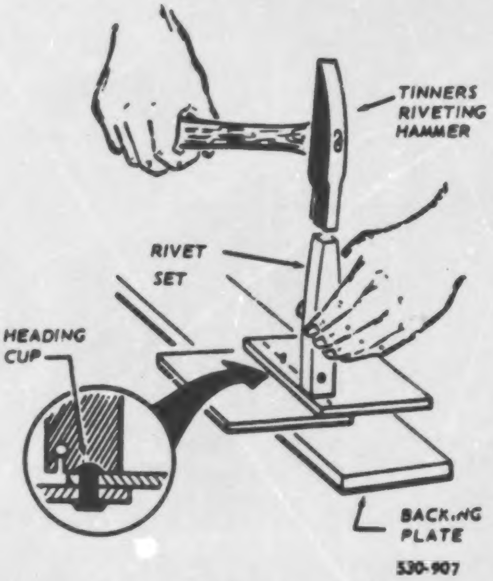


Figure 6. Heading rivets.

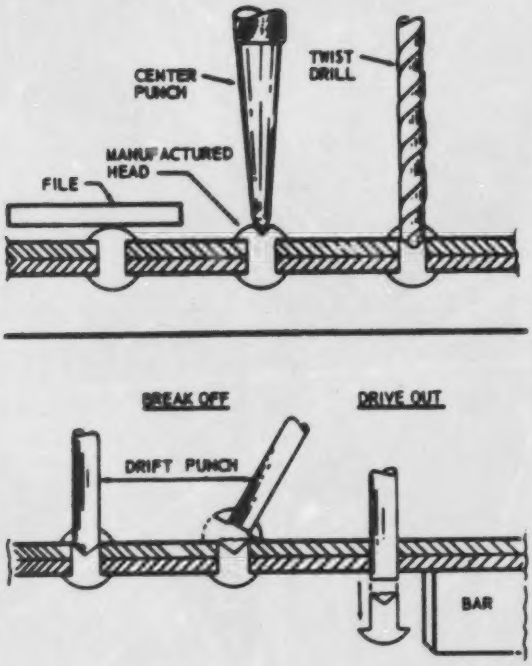


Figure 7. Removing a rivet.

bench stakes of various shapes are used. They are designed to overcome the interference and still have enough weight to support setting, upsetting, and heading. Hand dollies are sometimes called bucking bars. When riveting flat sheets where no interference exists, a flat steel plate secured to the work bench may be used.

1-18. **Drawing Rivets.** Drawing rivets is a process where drilling or punching holes is not necessary. This procedure is used with light gage sheet metal, such as 30, 28, and 26 gage. The rivet is placed head down on a bench plate or stake with the joint placed over the rivet. The joint is tapped lightly with a mallet to make an impression of the rivet shank. The set, shown in figure 4, is placed over the impression in the joint, and the set is tapped with a riveting hammer to draw the rivet through the light sheet metal. This method will prove useful when manufacturing funnels and cylinders and joining light sheets; it could be termed "using the rivet and set as a punch and die."

1-19. **Removing Rivets.** When removing a rivet, care should be taken to maintain the original size and shape of the rivet hole so that replacement with a larger rivet will not be necessary. If the rivet is not properly removed, the strength of the joint is weakened and replacement of additional rivets made more difficult.

1-20. When removing a rivet, drill the manufactured head, because it is more symmetrical than the shop made head and there is less chance of damaging the rivet hole or the metal around it. Rivets are removed with handtools, power tools, or a combination of both. The round manufactured head of a rivet should be filed flat and center punched for drilling, as shown in figure 7. (When center punching on thin sheet stock, back up the rivet on the upset head to avoid depressing or buckling the metal.)

1-21. A twist drill of the same size as the rivet shank is selected and the rivet head drilled out, as shown in figure 7. When a power drill is used, the point of the drill is set on the rivet and the chuck rotated several times by hand before turning on the power. This is done to help the drill cut a good starting spot, which will eliminate the possibility of the drill slipping off the rivet head and tracking the metal. The rivet is then drilled the depth of the head, making sure the drill is held at a 90° angle to the rivet head. The rivet head will usually break away and climb the drill as soon as the head is completely pierced. This is a good signal to cease drilling. Do not drill too deep as the rivet shank may fail to turn with the drill and cause the metal to tear. If the rivet head should fail to come loose of its own accord, insert a drift punch in the hole, as shown in figure 7, and twist slightly to either the left or right until the head comes off the rivet.

1-22. The final step is to drive the rivet out with a drift punch slightly smaller than the diameter of the rivet shank. Light gage metal should be supported with a solid object, such as a bucking bar, when you drive out the shank of the rivet.

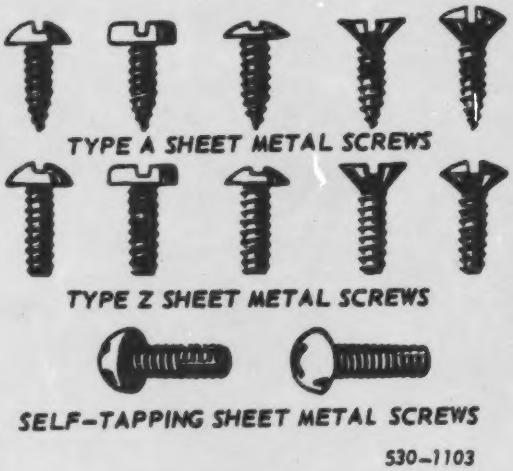

TYPE A SHEET METAL SCREWS
TYPE Z SHEET METAL SCREWS
SELF-TAPPING SHEET METAL SCREWS
530-1103

Figure 8. Sheet metal screws.

Diameter of Screw	Thickness of Metal		Pierced Hole	Drilled or Clean-Punched Hole	
	Number of Gage (US Std.)	Thickness	Diameter of Hole Required	Diameter of Hole Required	Drill Size
Nr. 4	28	.015"	.086"	.086"	44
	26	.018"	.086"	.086"	44
	24	.025"	.093"	.093"	42
	22	.031"	.098"	.093"	42
	20	.037"	.100"	.098"	40
Nr. 6	28	.015"	.111"	.099"	39
	26	.018"	.111"	.099"	39
	24	.025"	.111"	.099"	39
	22	.031"	.111"	.101"	38
	20	.037"	.111"	.106"	36
Nr. 8	26	.018"	.137"	.113"	33
	24	.025"	.137"	.113"	33
	22	.031"	.137"	.113"	33
	20	.037"	.137"	.116"	32
	18	.050"		.120"	31
Nr. 10	26	.018"	.158"	.128"	30
	24	.025"	.158"	.128"	30
	22	.031"	.158"	.128"	30
	20	.037"	.158"	.136"	29
	18	.050"	.158"	.149"	25

530–908

Figure 9. Holes and drill sizes for type A sheet metal screws.

2. Fastening Sheet Metal Components with Screws, Bolts, and Nails

2-1. You need to know the kinds of screws, bolts, and nails that are used in sheet metalwork, including their names, sizes, shapes, type of metal, and uses. This information will enable you to use the proper fastener for the job and help you to obtain the correct fasteners from supply. Bolts and screws used in the sheet metal shop are usually made from iron, steel, aluminum, or stainless steel.

2-2. **Sheet Metal Screws.** Sheet metal screws are frequently used in locations that make riveting difficult or for fastening sheet metal parts that may later be disassembled. If the hole is drilled or punched to the proper size, sheet metal screws are easily installed as they form their own threads in the metal during installation. If the hole is too small, the sheet metal screw, which is hardened, may break, making removal difficult. Three types of sheet metal screws (type A, type Z, and self-tapping) are illustrated in figure 8. Notice that type A and type Z have several different head styles; reading from left to right, they are roundhead, pan head, stove head, countersunk flathead, and countersunk ovalhead.

2-3. *Type A sheet metal screws.* Type A sheet metal screws have a sharp point and resemble a wood screw except that the threads are more

Diameter of Screw	In Sheet Steel					In Aluminum, Die Castings, Etc	
	Thickness of Metal		Pierced Hole	Drilled or Clean Punched Hole		Diameter Hole Required	Drill Size
	Nr. of Gage (US Std)	Thickness	Diameter Hole Required	Diameter Hole Required	Drill Size		
Nr. 6	28	.015"	.106"	.104"	37	.128"	30
	26	.018"	.106"	.104"	37		
	24	.025"	.106"	.106"	36		
	22	.031"	.110"	.106"	36		
	20	.037"	.110"	.110"	35		
	18	.050"	-	.11[illegible]	34		
	16	.062"	-	.116"	32		
	14	.078"	-	.120"	31		
	12	.109"	-	.128"	30		
Nr. 8	26	.018"	.131"	-	-	.152"	24
	24	.025"	.131"	.116"	32		
	22	.031"	.131"	.116"	32		
	20	.037"	.136"	.116"	32		
	18	.050"	.140"	.128"	30		
	16	.062"	-	.136"	29		
	14	.078"	-	.140"	28		
	12	.109"	-	.149"	25		
	1/8	.125"	-	.149"	25		
	10	.140"	-	.152"	24		
Nr. 10	26	.018"	.144"	.144"	27	.177"	16
	24	.025"	.144"	.144"	27		
	22	.031"	.144"	.144"	27		
	20	.037"	.147"	.144"	27		
	18	.050"	.155"	.144"	27		
	16	.062"	-	.152"	24		
	14	.078"	-	.157"	22		
	12	.109"	-	.161"	20		
	1/8	.125"	-	.169"	18		
	10	.140"	-	.169"	18		
	8	.171"	-	.173"	17		
Nr. 12	24	.025"	.185"	.166"	19	199"	8
	22	.031"	.185"	.166"	19		
	20	.037"	.185"	.166"	19		
	18	.050"	.185"	.169"	18		
	16	.062"	-	.177"	16		
	14	.078"	-	.182"	14		
	12	.109"	-	.185"	13		
	1/8	.125"	-	.196"	9		
	10	.140"	-	.196"	9		
	8	.171"	-	.201"	7		
Nr. 14	22	.031"	.209"	.185"	13	.234"	15/64
	20	.037"	.209"	.185"	13		
	18	.050"	.209"	.191"	11		
	16	.062"	-	.199"	8		
	14	.078"	-	.204"	6		
	12	.109"	-	.209"	4		
	1/8	.125"	-	.228"	1		
	10	.140"	-	.228"	1		
	8	.171"	-	.234"	15/64		
	13/16	.187"	-	.234"	15/64		
	6	.203"	-	.234"	15/64		

530–909

Figure 10. Holes and drill sizes recommended for type Z and self-tapping sheet metal screws.

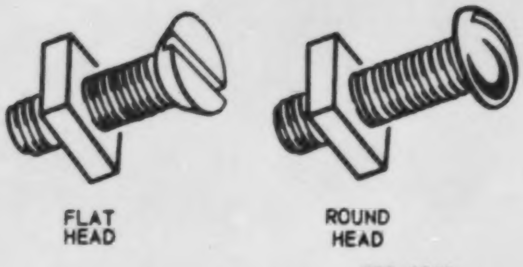


Figure 11. Stove bolts.

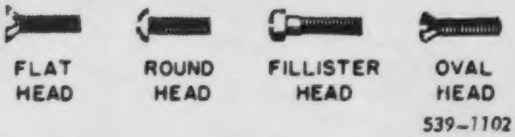


Figure 12. Machine screws.

coarse and extend to the head of the screw. These type A screws are recommended for joining and fastening light gages of sheet metal. Figure 9 lists the sizes of holes recommended for type A sheet metal screws.

2-4. *Type Z sheet metal screws.* Type Z sheet metal screws have blunt points and the same threads as type A; they are recommended for joining and fastening light or heavy gages of sheet metal. Figure 10 illustrates the sizes of holes recommended for type Z sheet metal screws.

2-5. *Self-tapping sheet metal screws.* Self-tap-

American (National) Screw Thread Series							
NATIONAL COARSE THREAD SERIES MEDIUM FIT. CLASS 3 (NC)				NATIONAL FINE THREAD SERIES MEDIUM FIT. CLASS 3 (NF)			
Size and Threads	Dia. of body for thread	Tap Drill		Size and threads	Dia. of body for threading	Tap Drill	
		Pref'd dia. of hole	Nearest Stand'd Drill Size			Pref'd Dia. of	Nearest Stand'd Drill Size
				0-10	.060	.0472	3/64
1-64	.073	.0575		1-72	.073	.0591	#53
2-56	.086	.0682	#51	2-64	.086	.0700	#50
3-48	.099	.078	5/64	3-56	.099	.0810	#46
4-40	.112	.0866	#44	4-48	.112	.0911	
5-40	.125	.0995	#39	5-44	.125	.1024	#38
6-32	.138	.1063	#36	6-40	.138	.113	#33
8-32	.164	.1324		8-36	.164	.136	#29
10-24	.190	.1472	#26	10-32	.190	.159	#21
12-24	.216	.1732	#17	12-28	.216	.180	#15
1/4-20	.250	.1990	# 8	1/4-28	.250	.213	# 3
5/16-18	.3125	.2559	# F	5/16-24	.3125	.2703	I
3/8-16	.375	.3110	5/16"	3/8-24	.375	.332	Q
7/16-14	.4375	.3642		7/16-20	.4375	.386	W
1/2-13	.500	.4219	27/64"	1/2-20	.500	.449	7/16"
9/16-12	.5625	.4776		9/16-18	.5625	.506	1/2"
5/8-11	.625	.5315	17/32"	5/8-18	.625	.568	9/16"
3/4-10	.750	.6480	41/64"	3/4-16	.750		11/16"
7/8-9	.875		49/64"	7/8-14	.875		51/64"
1-8	1.000		7/8"	1-14	1.000		59/64"

530–1153

Figure 13. American (National) screw thread sizes.

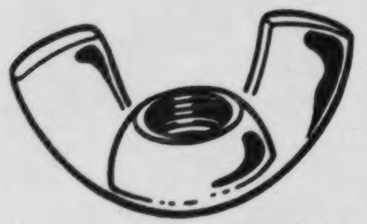


Figure 14. Wing nut.

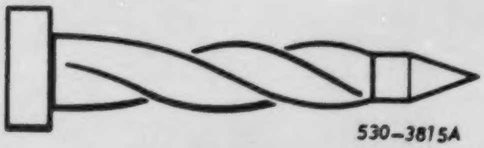


Figure 15. Screw nail.

ping sheet metal screws illustrated in figure 8 are recommended for heavier gage sheet metal, since they form threads while being screwed into the proper size hole. This sheet metal screw is also available with a hex head for use with socket wrenches. Figure 10 lists the sizes of holes recommended for self-tapping sheet metal screws.

2-6. **Stove Bolts.** Stove bolts, illustrated in figure 11, were originally developed for use on stoves, as the name suggests. They are small and can be used for many jobs where accuracy and strength are not required and where vibration will not shake the nuts loose. Stove bolts have coarse threads and are normally made of iron; they may be plated to prevent corrosion. Stove bolts may be obtained with roundheads, flatheads, or ovalheads. When you order or draw stove bolts from supply, the kind of head, diameter, threads, length, and finish are required to determine the stock number. For example: bolt, stove, steel, roundhead, ¼"-20 by 1" cadmium plated.

2-7. **Machine Screws.** The term "machine screw" is the general term used to designate small screws which may be used in tapped holes or with nuts. Most machine screws have fine threads and are made of steel or brass; they may be plated to prevent corrosion. A variety of diameters, lengths, and head shapes are manufactured, some of which are shown in figure 12. When you order or draw machine screws from supply, the kind of head, diameter, threads, length, and finish are required to determine the stock number. For example: screw, machine, roundhead, 8-32 by 1", cadmium plated. Figure 13 is a list of American (National) screw thread sizes and tap drill sizes.

2-8. **Nuts.** When sheet metal parts are being fastened with stove bolts or machine screws, it is necessary to use nuts of the same size and thread. The size of the nut is determined by the diameter of the bolt or screw it is to fit. For example: a $\frac{3}{16}$-inch nut will fit a $\frac{3}{16}$-inch bolt or screw if the threads are the same. Nuts may be made of brass, steel, or iron, or they may be plated the same as the bolt or screw. Nuts are made in several shapes, such as square, hexagon, wing, self-locking, and sheet spring. Many other shapes are available, but these are the most common in sheet metalwork.

2-9. Square nuts are square shaped as the name implies and are tightened with an open end wrench or adjustable wrench. Stove bolts usually have square nuts.

2-10. Hexagon nuts, commonly called "hex" nuts, have heads with six sides and are tightened with an open end wrench, adjustable wrench, box end wrench, or socket wrench. The box end and socket wrenches are recommended because they fit tighter and reduce the chance of rounding the corners of the nut. Machine screws normally have hex nuts.

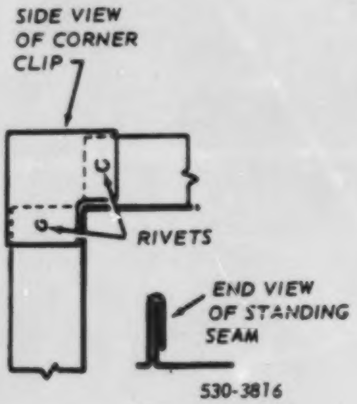


Figure 16. Clips.

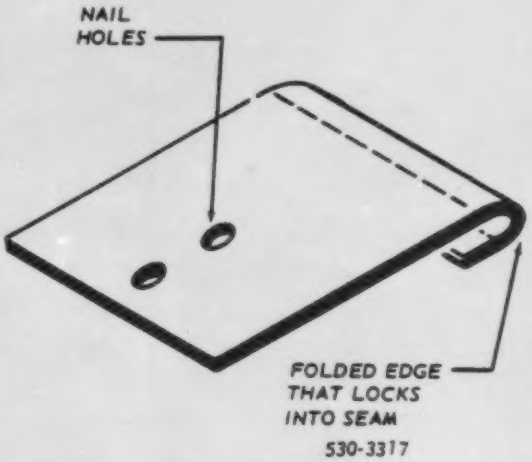


Figure 17. Cleat.

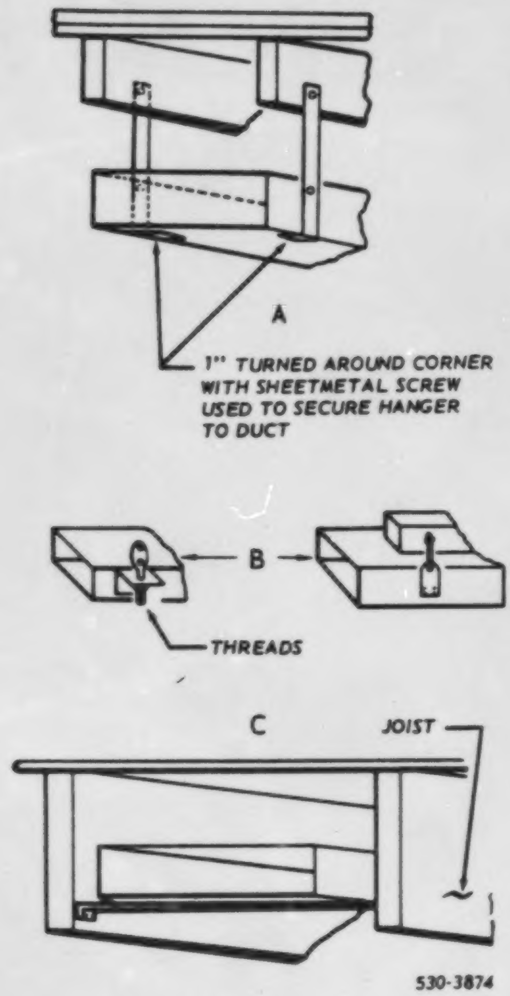

A
1" TURNED AROUND CORNER WITH SHEETMETAL SCREW USED TO SECURE HANGER TO DUCT
B
THREADS
C
JOIST
530-3874

Figure 18. Hangers.

2-11. Wing nuts, illustrated in figure 14, are identified by the wings extending from the two sides of the body of the nut. They are tightened by hand and used when easy or repeated removal is desirable.

2-12. Self-locking nuts differ from the nuts already described, because they have a locking device built in or secured to the nut to act as a binder. They are usually hexagon shaped and are held in place while the machine screws are installed. Self-locking nuts are used where vibration is encountered.

2-13. Sheet spring nuts are manufactured from sheet spring material, usually steel, into varying flat, concave, bent, or curved designs. The hole in the spring nut has internal lugs or prongs that are capable of securely gripping the threads of a screw or bolt. Flat spring nuts must be held in place while a bolt or screw is installed. Other spring nuts are folded like a clip and will stay in place while a bolt or screw is installed. Folded spring nuts can be used only near the edges of sheet metal; the metal parts being joined must have a hole drilled or punched to allow a bolt or screw to pass through.

2-14. **Nails.** Nails are manufactured in many sizes and shapes and are used with many types of material. Some are coated for resistance to corrosion and for increased holding power in wood. The shank of the nail may be spiraled, such as the screw nail illustrated in figure 15. The screw nail has replaced the common nail for attaching sheet metal to wood, since it has greater holding power. Also the screw nail is made from harder material than ordinary nails and can be driven through light gage sheet metal without first drilling a hole. The size and type of nail is determined

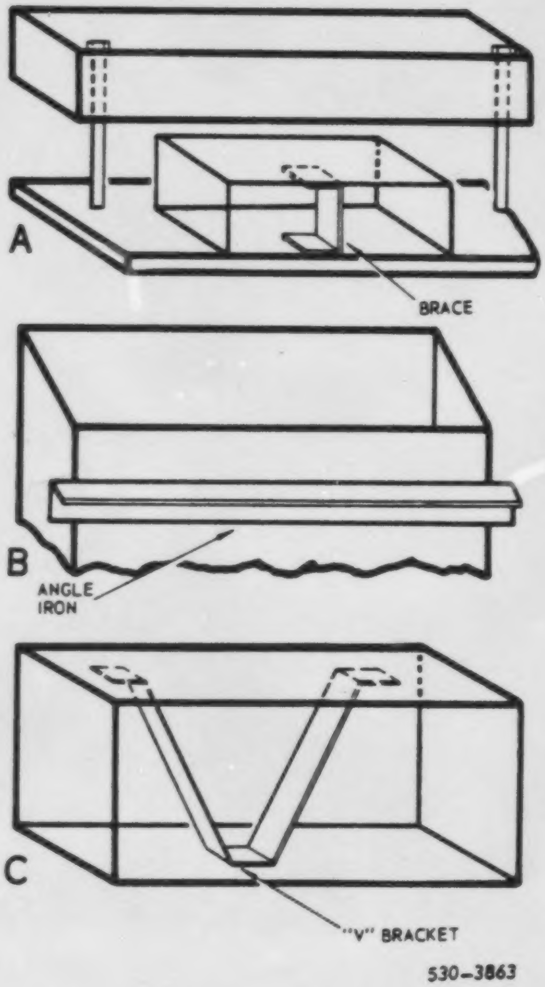


Figure 19. Braces.

by the strength desired and the thickness and location of the material into which it is driven.

3. Fastening Sheet Metal Components with Clips, Cleats, Hangers, and Braces

3-1. In the previous two sections you have learned how hardware, such as rivets, bolts, screws, and nails, is used for fastening sheet metal components and assemblies. In this section we discuss clips, cleats, hangers, and braces, which are used to fasten sheet metal components and assemblies. These fastening devices are usually fabricated in the sheet metal shop to fit a particular assembly or component. Although only a few of the many variations of these devices are described here, the illustrations will give you a good idea of how the devices are used, and it will not be difficult for you to make adaptations for similar sizes, shapes, and uses.

3-2. **Clips.** Clips are used to dress and strengthen corners of sheet metal assemblies that have been notched or damaged. Figure 16 is an example of how a clip is used to strengthen the corner of a standing seam. The size and shape of the clip is determined by the size and shape of the corner, joint, or seam being strengthened.

3-3. **Cleats.** Cleats are fasteners used to secure metal flashing and roofing. The cleat is nailed at one end to the roof and the remainder is formed into the seams. Cleats may be used with standing or grooved seams. The length of cleats is determined by the seam being used; however, the width should not exceed 2 inches. Figure 17 is an example of one type of cleat used with galvanized sheets—notice the location of the holes. When you install soft copper roofs, the cleats should have nail holes located near the end so that ½ inch of the cleat can be folded back over the nailheads; this prevents the nail from backing out and damaging the copper sheet.

3-4. **Hangers.** Hangers are used to support and level heating and air-conditioning ducts. Figure 18 illustrates some of the types and shapes you may use. The size and shape of the hanger will depend on the size, weight, and material of the duct it will support. The location and material of the structure supporting the hanger are other determining factors in selecting the type of hanger.

3-5. **Braces.** Braces are used when ducts are large and the sheet metal needs additional support and strength. Figure 19 illustrates three uses of braces; however, there are many other variations. The size and shape of the brace will depend on the size and shape of the assembly.

Sheet Metal Cutting Equipment

IN THIS CHAPTER you will study about many of the specialized tools and machines used for cutting sheet metal. The chapter contains five sections which concern maintenance of tools and equipment; hand snips and shears; shearing equipment; saws; and files, chisels, and grinders. The large shearing equipment includes the manually operated squaring shears, power operated squaring shears, and gap squaring shears. The smaller shearing equipment includes utility shears, throatless shears, scroll shears, circle shears, ring and circle shears, and unishears. Safety precautions are discussed where applicable.

2. The text, illustratrations, and questions will help you increase your knowledge and understanding of the purpose, function, use, and maintenance of sheet metal cutting equipment as speciifed in your specialty training standard. This chapter will also help you understand and apply safety practices and rules which are important. By following accepted accident prevention techniques, you can eliminate accidents when working with sheet metal cutting equipment. In fact, safe operation of cutting equipment may save your hands, fingers, or eyes.

3. The information you learn from this chapter will not only help you answer examination questions correctly but will also be used frequently during and after your training period. For example, you will be selecting cutting devices to cut various shaped articles from flat sheets, round stock, and angle iron. You must be able to select the proper equipment and use it correctly in order to produce articles of acceptable size and shape. You will repeatedly find that proper operation and maintenance of tools and equipment are important. There is an old saying among sheet metalworkers: "You can tell the way a man does a job by the way he maintains his tools."

4. Maintenance of Tools and Equipment

4-1. To get the maximum benefit from any tool or piece of equipment, we need two things—a trained operator and equipment that has been well maintained. As you gain experience you will learn how to maintain specific tools and equipment. For example, cutting equipment must be oiled, sharpened, adjusted, and used only for jobs for which it was designed. You should never overload a machine by cutting or bending material that is heavier than the capacity of the machine. The care and maintenance of most tools and equipment will be discussed in the various sections concerning each specific item. General and specific rules should be posted (and enforced) in every shop as to the use, care, and repair of all tools and equipment. These general and specific rules should also include safety precautions from such sources as AFM 127-101, *Accident Prevention Handbook*; manufacturer's handbooks; and technical manuals. Most of the suggestions of "don't" and "do" which follow are self-evident; nevertheless, they serve to emphasize the importance of proper tool use and care.

4-2. *Don't* pile handtools on top of one another on the workbench or in the toolbox. When tools, such as snips, files, hacksaws, chisels, and hammers are scattered and piled on the bench, they will likely become damaged. If tools are piled upon each other, the tool you want always seems to be on the bottom of the pile; therefore, time is lost and your patience is frayed looking for the right tool. Why not hang them up as you finish using them?

4-3. *Don't* put a tool away without first cleaning it, especially if the tool is wet or has been used on oily material. Excess oil will pick up dirt and dust, and moisture will cause rust to occur. Remember, too, that some greases and oils have corrosive properties that may damage the finish on the tool.

4-4. *Don't* leave tools or any other articles on beams, rafters, or any other overhead location. The least that could happen (besides forgetting where you left it) would be a broken tool, and the worst thing could be injury, should it drop on anyone below.

4-5. *Don't* use screwdrivers for chisels.

4-6. *Don't* overload cutting machines by exceeding the recommended cutting capacity.

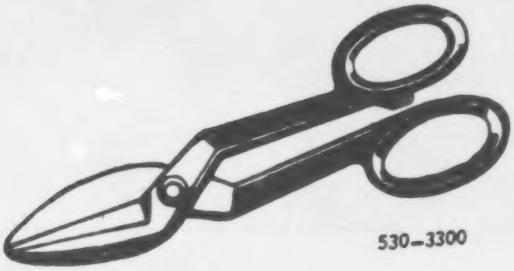


Figure 20. Straight snips.

4-7. *Do* keep hand, bench, and power tools sharp, in adjustment, and in top mechanical condition at all times.

4-8. *Do* have a regular and definite time every day to check your tools for condition. While checking for condition, you can also determine if any have "strayed" off since the last check.

4-9. *Do* sharpen, adjust, and/or repair (if the tool is reparable) any tool needing such maintenance. If tools are not reparable, exchange them at the tool crib.

4-10. The items of cutting equipment in your shop could have mainteance performed on them at different intervals. A maintenance record folder is kept on the equipment to log the maintenance that has been performed and when it was performed. Manufacturers' handbooks or technical manuals for the equipment will contain detailed instructions concerning frequency of inspections and servicing procedures. For example, the inspection on a power hacksaw, such as that illustrated in figure 37, is usually accomplished every 90 days and includes inspection for damage, wear, and fluid condition. Maintenance of a typical power hacksaw includes lubrication where required, making adjustments as needed, cleaning the cutting fluid strainer and reservoir, refilling with clean fluid of the correct mixture, cleaning all unpainted parts with a slightly oiled rag, and cleaning all painted parts with a dry rag or with a rag moistened with soap and water. The power hacksaw blade may or may not be replaced during preventive maintenance, since it is usually replaced by the operator as needed.

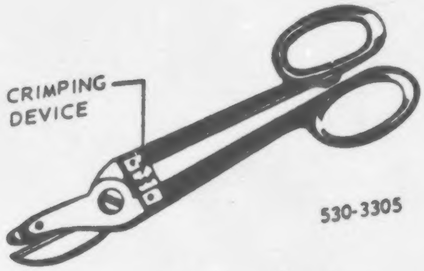


Figure 21. Double cutting shears.

4-11. The preventive maintenance performed on other sheet metal cutting equipment is similar to the items listed for the power hacksaw except for the cutting fluid and strainer.

4-12. Other repair on pieces of sheet metal cutting equipment may be performed by personnel from the civil engineer maintenance mechanic shop or at a depot.

5. Hand Snips and Shears

5-1. You will find many uses for hand snips and shears, such as cutting out light gage sheet metal parts. There will be many times, when working away from the shop, that your handtools will be all you have to do a job with. Therefore, it is necessary for you to know how to use the tools in your toolkit. Use the appropriate snips or shears with the correct capacity for the job. The snips and shears you will be using are for cutting straight lines, inside and outside circles, and irregular curves.

5-2. Snips and shears are designed to cut only sheet metal; cutting wire or rod will damage the cutting blades. Keep snips in good working condition by proper use, sharpening when necessary, applying a light coat of oil to prevent rusting, and oiling the hinge bolt to make operation easier. Hinge bolts in snips and shears should be kept snug but not too tight since a tight hinge bolt will make operation harder, while a loose hinge bolt will prevent a clean cut because the metal will fold rather than cut. Sometimes snips or shears with a loose bolt will cut but leave a rolled edge.

5-3. **Straight Snips.** Straight snips are designed to cut straight or long curved lines in sheet metal. The straight snips shown in figure 20 are available with right-hand cut for right-handed people and with left-hand cut for left-handed people. You will use straight snips for cutting sheet metal for such items as pans, rectangular ducts, and other similar jobs. With straight snips you can cut sheet metal from 30 gage to 20 gage with very little effort. Bulldog snips (not illustrated) can be used for cutting sheet metal from 20 to 16 gage, although it is difficult to cut these heavier gages with hand operated snips.

5-4. **Double Cutting Shears.** Double cutting shears, illustrated in figure 21, have a cutting edge on both sides of the blade and will cut on either side, as their name suggests. These shears will prove useful when cutting sections of vents or round conductors for gutters. For instance, if you need to cut a 3-foot piece of vent pipe from a 10-foot joint, start a hole large enough to insert

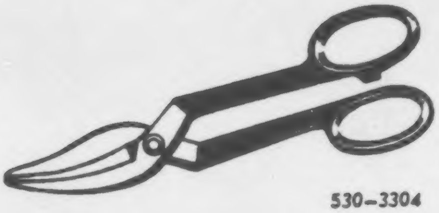


Figure 22. Circle snips.

the cutting blade. A ½-inch cold chisel will easily cut the starter hole. The hole should be made close to the seam since the metal is stiff at this point and will cut easier. When making cuts away from the shop, you will normally have to crimp one end of the joint so it will slip inside the other. Double cutting shears usually have a crimping device which can be used. These shears are for light gage metal, so do not attempt to cut through the seam where the metal is much thicker. Straight snips should be used to cut the seams.

5-5. **Circle Snips.** Circle cutting snips, illustrated in figure 22, have curved blades and are designed to cut circles or inside scrolls in light gage metal. You will find them useful for jobs such as cutting a circle in a flat sheet into which a round piece of pipe is to be inserted or joined. Like double cutting shears, the circle snips require a starting hole when cutting inside circles. These snips will prove useful in the shop and in the field when you are doing jobs that involve light gage metal.

5-6. **Bench Shears.** Bench shears, illustrated in figure 23, are designed to cut heavy gage sheet metal from 20 to 16 gage. The bottom handle of the bench shears is shaped to fit into the bench plate so that the shears can be operated with one handle. Bench shears are useful for jobs such as corner notching and straight cutting.

5-7. **Aviation Snips.** The aviation snips which you will be using are illustrated in figure 24; they are available in left- or right-hand cut. This means two pairs of snips are required, one for cutting to the left and one for cutting to the right. It does not mean that they are made for left- and right-handed people as in the case of straight snips. The blades of avaition snips are designed to cut small holes and irregular outlines in heat-treated aluminum alloy or stainless steel. The handles are of the compound lever type and will cut mild steel as thick as 16 gage. You will find these snips very useful in the field for cutting any shape of holes in ducts, panels, and similar jobs.

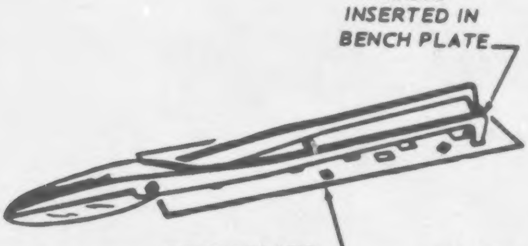


Figure 23. Bench shears.

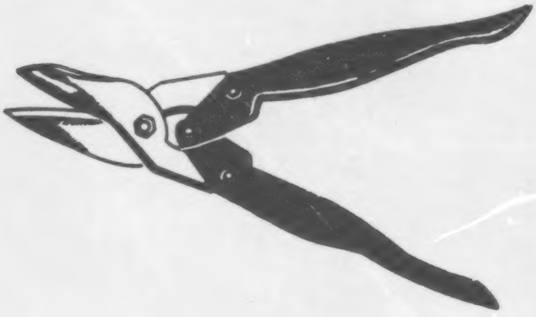


Figure 24. Aviation snips.

6. Shearing Equipment

6-1. Although handtools are indispensable for the sheet metalworker, a man is very limited in the amount of material he can produce by hand; therefore, he continually strives for greater production or easier ways to turn out work. Because of this necessity for increased production to meet demands, laborsaving machines are constantly being perfected. Within his field, every sheet metalworker is a machine operator in addition to his other skills.

6-2. One thing to be remembered when you are using any sheet metal machine is that it has a specific limit as to what materials it can process. If the metal is too thick, the machine will be damaged. Posted in some convenient place on each machine is the manufacturer's data plate which tells the capacity of the machine. Read this information carefully and follow the instructions.

6-3. Do not attempt to use shearing equipment unless you have received checkout instructions and are authorized to operate such equipment.

6-4. **Power Operated Squaring Shears.** Squaring shears, illustrated in figure 25, provide a convenient means of cutting and squaring sheet metal. It is important to learn how to use this tool because it will, among other things, increase production.

6-5. This machine consists of a lower blade that is stationary on the bed of the shear, an upper blade that is attached to the crosshead, and a holddown clamp to hold the metal securely

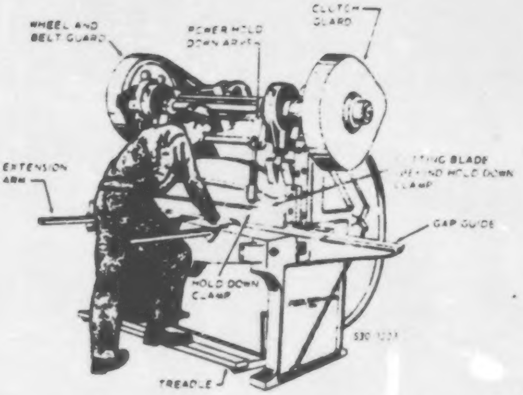


Figure 25. Power operated squaring shears.

during cutting. The holddown clamp allows the operator to get his hands out of the way during the cutting operation. The table of the power shears has extension arms which provide support for long sheets of metal. Extending to the right of these arms, but still on the bed, is a guide graduated in sixteenths of an inch. This guide can be used as a measuring scale for cutting short lengths of metal. It also keeps the metal square with the blade when adjusted correctly. The guide is not shown in figure 25 since the machine as illustrated is set up to cut long sheets of metal. However, it is similar to the side gage of the manually operated squaring shears, shown in figure 26. Control switches are provided for operating the power shears. The back gage is adjustable and can be moved forward or backward, depending on the length of cut required. There is no need to measure between the back gage and the fixed horizontal blade because all measurements can be read on the back gage, which is graduated in sixty-fourths of an inch. By depressing the treadle, you engage an automatic clutch which sets the shearing blade in action. The shears will go through only one cycle of action each time the treadle is depressed and released. If continuous operations are desired, simply continue to hold the treadle in the down position. Once the treadle is released, the machine stops when it completes the cycle of operation. Be sure to turn off the shears after all cuts are made and remove the material that has just been cut.

6-6. Before operating power shears you should check the machine to see that it is clear of material and personnel. For instance someone might be making repairs behind the machine. If power to the machine is turned off, there is usually a reason; therefore, check with your supervisor for the cause. In some shops a "Caution Repair" tag may be used to identify the status of the machine. If there is such a tag on the machine, do not attempt to remove the tag. The person making repairs will do the removing when the work has been completed. The machines you use are equipped with guards for your protection, and they should never be removed, except when the machine is being repaired. The blade guard is not visible in figure 25, because it is located between the holddown and cutting blade. The blade guard is similar to the safety guard shown in figure 26. The blade guard is designed to keep your hands and fingers away from the cutting blades during operation of the machine. Wheel and belt guards are provided to protect personnel and to keep foreign objects from being caught in the moving parts. When making cuts, always make certain the cutting blades are clear before releasing the clutch to actuate the blade.

6-7. **Manually Operated Squaring Shears.** These shears are a great deal like power operated squaring shears except that the foot supplies the action and power required to operate the cutting blade. In addition, the back gage and holddown handles are manually operated. True, there are quite a variety of foot operated shears manufactured, but basically they are all made the same. If you can operate one successfully, you can operate the others.

6-8. The shears illustrated in figure 26 have a large spring at each end of the housing which raises the blade when pressure is removed from the treadle. A scale, graduated in fractions of an inch, is scribed on the bed as a guide for cutting correct lengths. At each end of the bed there is a side gage which aids in keeping the metal square with the blades. If, after the first cut is made, it is found that the cut is not square, the error can be corrected by loosening the locking

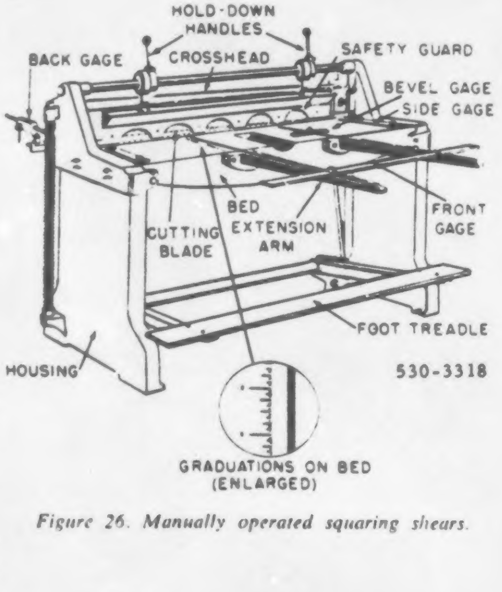


Figure 26. Manually operated squaring shears.

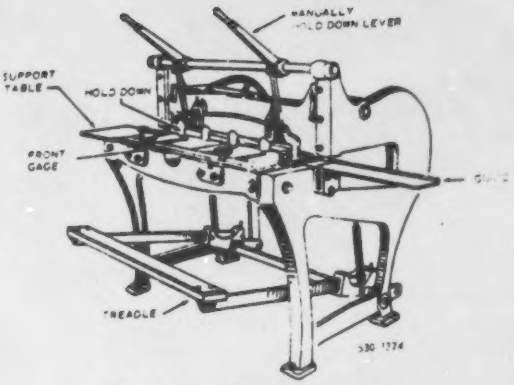


Figure 27. Gap squaring shears.

bolts and readjusting the side gage. If it is necessary to cut long sheets of metal that must be pushed from the back side, the two extension arms can be used in conjunction with the front gage. The sheet metal gage limit of this particular shearing machine is usually 16-gage mild carbon steel. If the metal is heavier, use power shears.

6-9. The holddown attachment on foot operated shears can be either spring actuated or manually controlled. These holddowns, if adjusted properly, have decided advantage over handholding of the materials, which usually allows the material to slip, causing inaccurate cuts. Only on very light or short cuts can accuracy of cut be maintained on material held by hand.

6-10. The squaring shears perform many necessary operations which save a great deal of work. These jobs are cutting to a line, squaring, and multiple cutting to a specific size. When cutting to a line, place the sheet on the bed of the shears in front of the cutting blade, with the cutting line even with the cutting edge of the bed. Pull the holddown handles forward to lock the metal in place. Then cut the material by stepping on the treadle, which initiates the cutting cycle.

6-11. Squaring a piece of metal requires several steps, the first of which is the trimming of one edge. This is done by inserting the metal between the blades of the shears and cutting off approximately one-quarter of an inch of metal. The remaining edges are squared by holding a trimmed edge against the side gage and making the remaining cuts, one edge at a time, until all edges have been squared.

6-12. When cutting several pieces of metal to the same dimensions, use the back gage (production gage). This gaging device, shown in figure 26, consists of two support rods, graduated in fractions of an inch, and a square fence that can be set at any point on the support rods. To use the gage, set the squaring fence at the desired distance from the cutting blade by loosening the locking knobs and turning the adjusting knobs. Lock the fence in position after all adjustments have been made, and insert the metal between the blades of the shears until the edge of the metal comes in contact with the squaring fence. To insure accuracy of cut, be sure that the edge of the metal is flush all along the fence. When this is done, pull the holddown handles to clamp the metal. The successful use of this gage depends upon a few predetermined adjustments, and once the gage adjustments are made, many pieces of metal can be cut to the same dimension without additional measuring.

6-13. Safety precautions to be observed when using manually operated squaring shears are practically the same as those for power operated squaring shears. One exception is that when pushing down on the foot treadle, which requires considerable force, be sure your other foot is clear of the foot treadle.

6-14. **Gap Squaring Shears.** The gap squaring shears, illustrated in figure 27, resemble manual squaring shears except that the frame is built to accommodate any width or length of sheet metal for slitting. The front opening or gap is usually about 18 inches deep for shears with a capacity of 16-gage mild steel. These shears have a supporting table on the left side to keep the sheet level with the surface of the bed; on the right side is another guide which is used in slitting long sheets of metal. Constructed as they are, these shears can be used to cut one piece or several pieces from a sheet of metal longer than the machine itself. This type of work is done by first adjusting the front gage to the desired width, making sure that the gap is deep enough to allow easy passage of the metal. The metal is moved

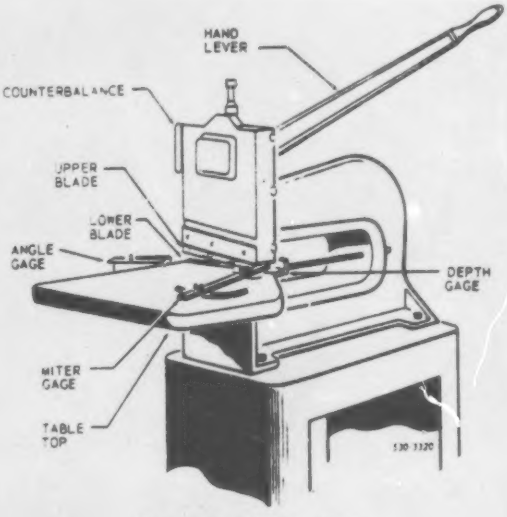


Figure 28. Utility shears.

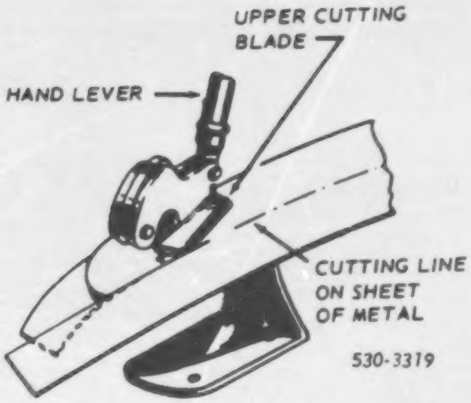


Figure 29. Throatless shears.

between the cutting blades from left to right and a cut is made about three-quarters the length of the blade. Then the holddown levers are released and the sheet moved to the right so that the edge of the metal will ride against the guide. This is repeated until the cut is completed.

6-15. Safety precautions to be observed when operating gap squaring shears are similar to those precautions for manually operated squaring shears.

6-16. **Utility Shears.** The type of utility shears shown in figure 28 is used for general work around a sheet metal shop and is especially useful for cutout work, such as angles and miter joints. The lower blade is attached to the table so that it is easy to cut to the line with accuracy. The scribed line is always visible to the operator, thus permitting outside, straight, and irregular cutting. The upper blade moves up and down by means of a counterbalanced hand lever. In most cases, utility shears are equipped with an angle gage, miter gage, and depth guide. These gages assist in cutting duplicate pieces of metal to a desired size and shape without repeated marking and adjusting.

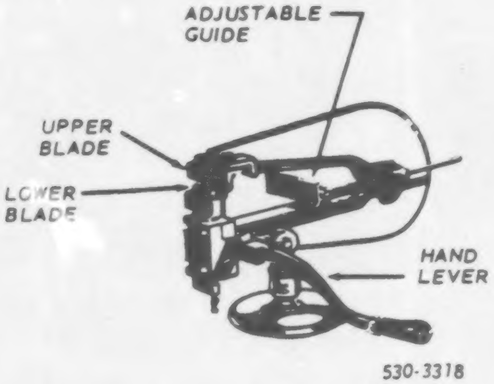


Figure 30. Scroll shears.

6-17. The cutting blades of utility shears vary in size from 6 to 9 inches and have a throat in the frame ranging from 9 to 20 inches. This machine is limited to cutting mild steel of 10 gage or less. Make sure the gage of the metal is within the capacity of the machine before making any cuts.

6-18. When operating utility shears, be careful to keep fingers away from the cutting blades. During cutting operations, be sure to return the counterbalanced hand lever to the full up position to prevent it from accidentally lowering the upper cutting blade.

6-19. **Throatless Shears.** These shears, illustrated in figure 29, get their name from their construction because the frame is "throatless," and there are no obstructions during cutting. Therefore, a sheet of any length may be cut, and the metal can be turned in any direction to allow for cutting irregular shapes. The cutting blade (top blade) is operated by a hand lever. An example of the use of throatless shears is the cutting of a rectangular elbow from 16-gage sheet metal. Radius cuts in this heavier gage metal can be made easily with throatless shears. Safety precautions include keeping fingers away from the cutting blades, returning the handle to full up position after the cutting operation, and protecting fingers and hands from burrs when guiding metal through the cutting blade.

6-20. The bottom (fixed) blade should be kept in proper adjustment; if the blades are too close, they lose their sharpness and may be damaged. If the blade gap is too wide, the metal will have a tendency to fold, causing a bad cut. The lower blade is adjusted with setscrews.

6-21. **Scroll Shears.** The scroll shears, illustrated in figure 30, are used for cutting circles, ovals, and straight or irregular lines at almost any location on the sheet. Scroll shears, like other shears already mentioned, have a guide to regulate the length of cut. An example of a job you may encounter, where scroll shears are valuable, is in the making of a louvered cover for an electric motor. The louver slits can be made without making starter holes or stretching the metal. After the metal has been slit, it may be easily louvered by using form blocks or machines.

6-22. The upper blade of scroll shears is adjusted similar to that of the throatless shears. Ordinary safety precautions, such as keeping fingers away from the cutting blades and burrs, should be observed.

6-23. **Circle Shears.** Circle shears, illustrated in figure 31, are used to greatest advantage when cutting circular blanks for such items as buckets, cans, and the usual run of cylindrical objects. These shears can also be used for slitting sheets and are equipped with a guide for that purpose.

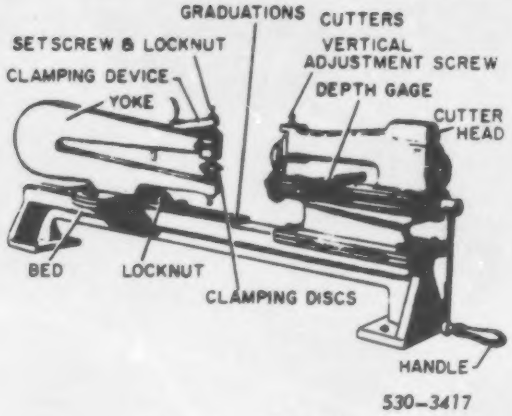

GRADUATIONS
CUTTERS
SETSCREW & LOCKNUT
VERTICAL ADJUSTMENT SCREW
CLAMPING DEVICE
YOKE
DEPTH GAGE
CUTTER HEAD
BED
LOCKNUT
CLAMPING DISCS
HANDLE
530-3417

Figure 31. Circle shears.

They are best suited for cutting discs from mild steel, copper, and aluminum.

6-24. The principal parts of the circle shears are the bed, yoke, and rotary cutters. The bed, since it must absorb and withstand the majority of the load and shock, is made of strong steel plate. On the top of this bed are graduations marked every sixteenth of an inch to indicate the approximate diameter of the circle you are cutting. The yoke, or sliding circle arm, centers and holds the sheet. The position of the yoke is governed by the diameter of the cut. To adjust the yoke, loosen the locknut (usually located at the base of the yoke) and slide it along the bed. Attached to the yoke is the clamping device, which is operated by a clamping handle. Setscrews and locking nuts are used to adjust the pressure on these clamping devices. There is also a hardened center pin in the lower disc which aids you in centering blanks of center punched metal.

6-25. The upper rotary cutter on this machine can be adjusted in a vertical position and should overlap enough to cut through the metal in one cut. The adjusting screw is usually located directly above the upper cutter. The bottom cutter can be adjusted in the same manner but in a lateral direction. For light gage metal, the cutters should just touch and operate freely. When cutting heavy material the cutters should be separated slightly, but this opening should be limited to a maximum of 10 percent of the metal thickness.

6-26. When you are cutting circular blanks with circle shears, the first job is to cut the metal to the approximate size. Place the blank between the clamping discs and adjust the yoke so that the distance from the center of the clamping discs to the cutting wheels is one-half the diameter of

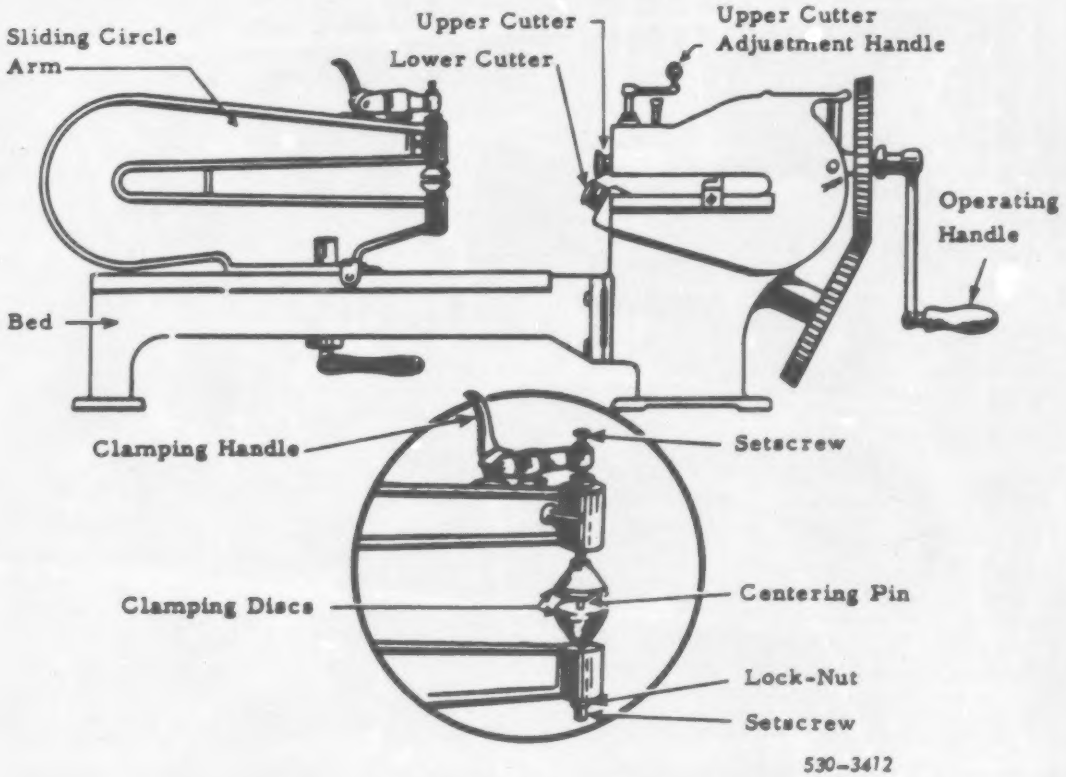

Sliding Circle Arm
Upper Cutter
Lower Cutter
Upper Cutter Adjustment Handle
Operating Handle
Bed
Clamping Handle
Setscrew
Clamping Discs
Centering Pin
Lock-Nut
Setscrew
530-3412

Figure 32. Ring and circle shears.

the blank desired. Then adjust the upper cutting blade with the vertical adjustment screw. You should stand at the side of the shears with the cutting head to your left when operating the machine with the handle so that the sheet metal will feed away from you. Do not attempt to cut inside circles with this machine, and always start the cut from the edge of the sheet.

6-27. Safety precautions when using circle shears include such items as keeping fingers from the cutters, gears, and burrs.

6-28. **Ring and Circle Shears.** The basic construction of the ring and circle shears, illustrated in figure 32, is similar to that of rotary circle shears. The main difference lies in the lower cutting head, which is set at an angle to the other cutter to permit the cutting of inside circles as well as discs and shallow concave curves. The lateral adjustment between the cutters is the same as for circle shears. Turning the adjustment handle to the left or right will obtain proper clearance between the cutters. Before you cut outside discs with the ring and circle shears, be sure to read the operational procedure for the circle shears.

6-29. To cut a inside circle (hole) in a sheet of metal, adjust the yoke of the ring and circle shears so that the distance from the center of the sheet to the cutter wheels is one-half the diameter of the desired circle. Place the metal between the clamping discs and secure it by lowering the clamping handle. Turn the upper cutter adjustment handle slowly in a clockwise direction. When cutting with the ring and circle shears, turn the operating handles so that the material is fed away from you. Do not lower the upper cutter any farther than is necessary to cut through the metal. Set the locknuts on the upper cutter adjustment handle so that the upper cutter produces a clean cut.

6-30. Safety precautions when you are using ring and circle shears are very similar to those listed for circle shears; however, some ring and circle shears are power operated, and the additional safety precautions include keeping clear of the sheet metal as it revolves during the cutting process. The foot switch can be moved away from the machine to help you stay clear. This foot switch is a source of possible danger, since it may be accidentally depressed by the foot or by a falling object. If the switch is accidentally actuated, the power operated ring and circle

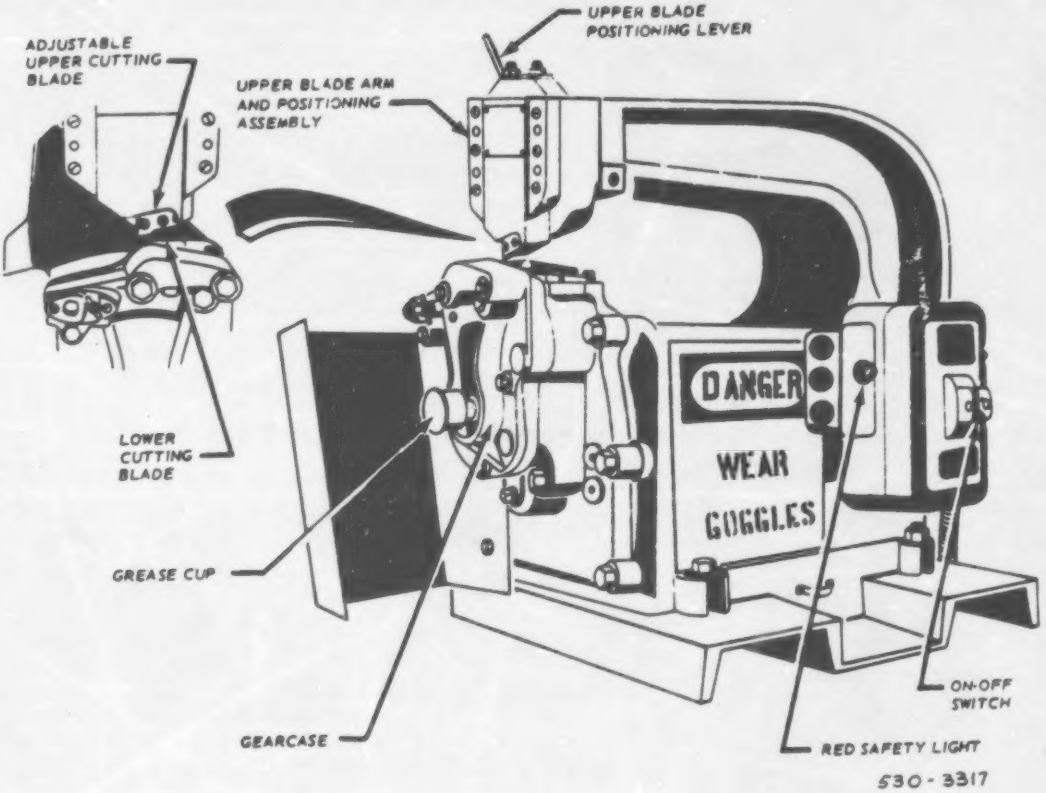

UPPER BLADE POSITIONING LEVER
ADJUSTABLE UPPER CUTTING BLADE
UPPER BLADE ARM AND POSITIONING ASSEMBLY
DANGER
WEAR GOGGLES
LOWER CUTTING BLADE
GREASE CUP
ON-OFF SWITCH
GEARCASE
RED SAFETY LIGHT
530-3317

Figure 33. Stationary unishears.

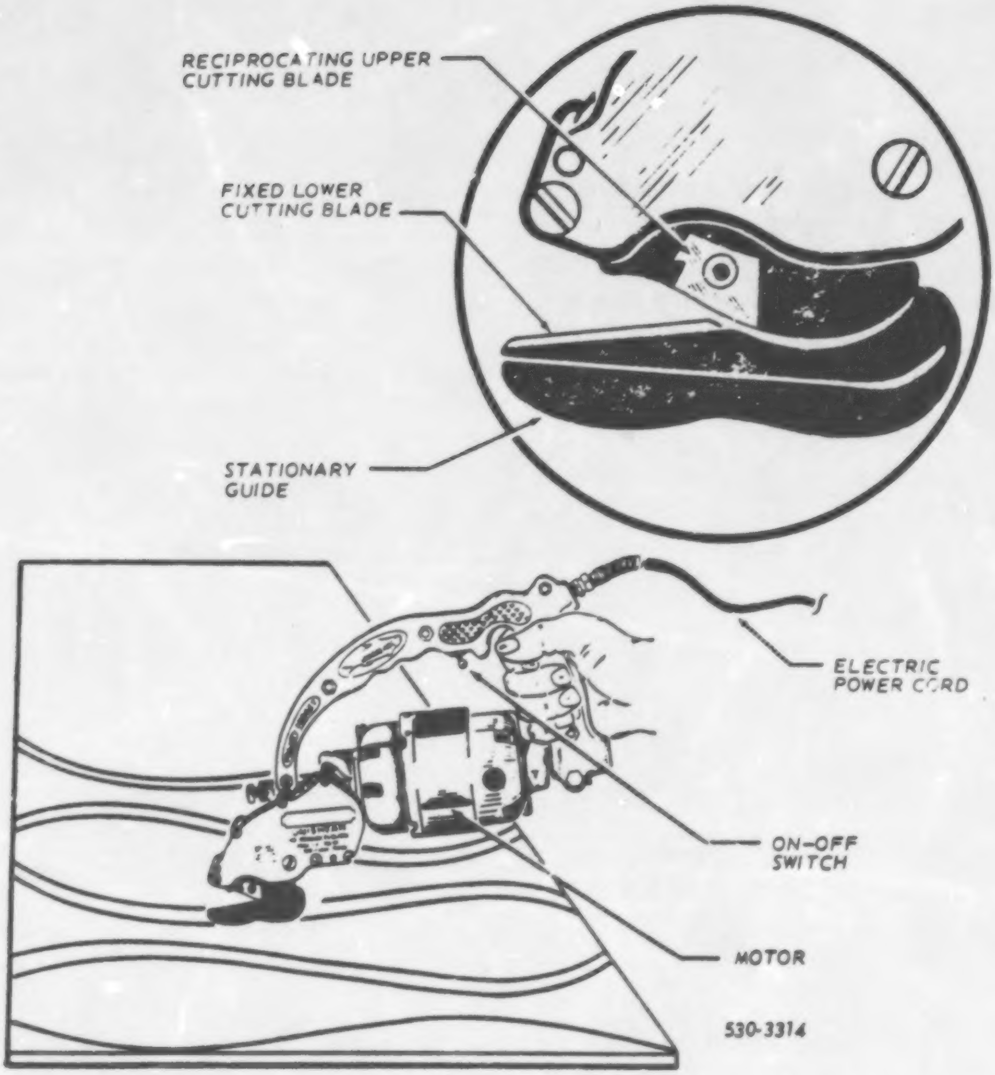


Figure 34. Portable unishears.

shears may start operating and cause damage to the material and danger to the operator. Still another source of danger to the operator is loose clothing which can snag on burrs or corners of the revolving metal, causing hands or fingers to be drawn into the cutter heads.

6-31. **Unishears.** You will find unishears useful equipment in the sheet metal shop. Figures 33 and 34 illustrate two types, stationary and portable. Both are designed to cut along irregular lines on sheet metal and will save you much time since they cut faster than hand snips or shears.

6-32. The *stationary unishears* illustrated in figure 33 is powered by an electric motor which moves the lower cutting blade up and down to cut sheet metal as it is guided through the blades. It is possible to make straight or irregular cuts through sheet metal as heavy as 16 gage. The upper cutting blade does not reciprocate during cutting; however, the upper blade positioning assembly can be raised with the upper blade positioning lever when it is necessary to open the throat of the shears to make inside cuts. The blade is lowered before the machine is operated. The cutting blades are adjusted for clearance when new blades are installed; therefore, they do not need readjustment, in most cases, for different gages of sheet metal. A red safety light located near the ON-OFF switch is illuminated when the motor is operating. The grease cup located in the gearcase is packed with gear lubricant and must be tightened by hand to lubricate the moving parts.

6-33. In figure 34 you can see how irregular cuts in sheet metal are made with electrically driven *portable unishears*. Notice how the shears are guided through the metal. This is rather easy to do because they are throatless and can be turned to the right or left without releasing the forward pressure. Portable unishears are held in your right or left hand and used in the shop or at the job if electrical power is available.

6-34. Accuracy when cutting with either the stationary or portable unishears is determined by the operator; therefore, it is important to align the upper cutting blade with the line being cut in the metal. If you look a few inches ahead of the cutting blades you should get better results. Apply just enough pressure to insure that the blades are cutting smoothly at all times. Too much pressure will overload the machine, and too little pressure will cause the metal or machine to jump from side to side resulting in very sharp burrs.

6-35. There are several safety precautions which you should observe when using either one of the unishears. Keep your hands and fingers clear of the cutting blades at all times, and avoid the sharp burrs. Also keep the power cord of the portable unishears clear of the burred edges to prevent damage to the insulation. Check the three-prong connector on the power cord before connecting it to a properly grounded power receptacle.

7. Saws

7-1. Saws used in the sheet metal shop include bandsaws, hole saws, hand hacksaws, and power operated hacksaws. These saws are used to cut light and heavy gage sheet metal, angle iron, pipe, and thin wall tubing. Each of the saws used for these jobs has certain characteristics which enable it to perform some jobs better than other saws can. As with other tools, you should select the right saw for the job. In the following sections we will discuss saws used in sheet metalwork, including their uses, maintenance, and safety precautions. We will also discuss various saw blades with respect to materials selected for cutting.

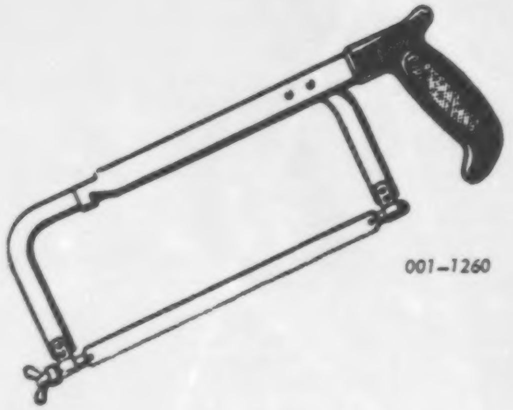


Figure 35. Hacksaw.

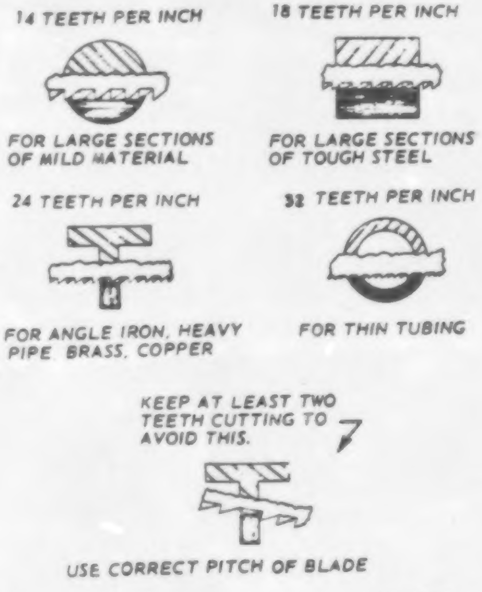

14 TEETH PER INCH
FOR LARGE SECTIONS OF MILD MATERIAL
18 TEETH PER INCH
FOR LARGE SECTIONS OF TOUGH STEEL
24 TEETH PER INCH
FOR ANGLE IRON, HEAVY PIPE BRASS, COPPER
32 TEETH PER INCH
FOR THIN TUBING
KEEP AT LEAST TWO TEETH CUTTING TO AVOID THIS.
USE CORRECT PITCH OF BLADE
001-1249

Figure 36. Correct sawtooth selection.

7-2. **Hand Hacksaws.** The hacksaw illustrated in figure 35 consists of a frame, handle, and blade. Hacksaw blades come in lengths 6 to 16 inches, although the 10-inch size is most commonly used. These blades are identified by length of blade and number of teeth per inch (or pitch). Blades with 14, 18, 24, and 32 teeth per inch are available. Blades are made of high grade tool steel which may be flexible or all hard. The flexible blades have only hardened teeth, whereas all-hard blades have hardened teeth and blades. Blade selection involves finding the right type for the job at hand, as illustrated in figure 36. An all-hard blade is best suited for sawing brass, tool steel, cast iron, and heavy cross sections of material. Flexible blades are recommended for sawing hollow shapes and material having thin cross sections. The selection of teeth is important, and the following example will aid you in making the correct selection. A blade with 14 teeth per inch is recommended for cutting cold roll and structural steel. The 18 teeth per inch blade is recommended for solid stock aluminum and cast iron. The 24-teeth-per-inch blade is recommended for cutting thick wall tubing, pipe, channel iron, and angle iron, as well as brass and copper. The blade you will most often use is the 32 teeth per inch, which is recommended for thin wall tubing and light gage sheet metal.

7-3. Always remember to install the blade in the frame with the angle of the teeth forward (away from the handle). When sawing, hold the saw at an angle that will allow at least two teeth to contact the cutting surface at all times. Use long strokes and apply just enough pressure on the forward stroke to cause each tooth to cut. Forty or fifty strokes per minute are sufficient to insure a good cut.

7-4. **Power Hacksaws.** Power hacksaws, such as that illustrated in figure 37, are designed to cut pipe, angle iron, bar stock, and heavy plate. The power hacksaw is equipped with an adjustable vicelike clamp to secure the material being cut. The clamp can be set for various miter cuts but will be used to make 90° cuts most of the time. The blades are approximately 1-inch wide and come in various lengths. The number of teeth per inch for power hacksaw blades is selected by the same criterion as that for hand hacksaw blades. As with other machines, you should read the operator's instructions or the technical manual before using this machine.

7-5. Before starting the power hacksaw, be sure that the material is clamped securely to prevent binding and breaking of the blade. The material thickness adjustment is set in various notches according to the material thickness. A blade broken while the saw is operating improperly may shatter and endanger personnel. If your power hacksaw is equipped with a blade lubricating device, be sure to keep the fluid strainer clean and to mix the cutting oil according to the manufacturer's specifications. Proper use of cutting oil means longer blade life and improved performance of the saw.

7-6. **Bandsaws.** Your shop will normally be equipped with an upright or horizontal type bandsaw. The upright, such as the DOALL saw shown in figure 38, is designed to cut straight or irregular cuts. With a proper blade and using the job selection dial as a guide, you may adjust this machine to cut many types of metal. The saw illustrated may be hand or power fed; however, you will use the manual feed process most of the time. Be safety conscious at all times.

7-7. The horizontal bandsaw (not illustrated) is designed to make straight cuts; the blade runs horizontal to the cutting surface similar to a power hacksaw. Some horizontal bandsaws are equipped with a blade lubricating device similar to the power hacksaw. The vice type clamp on the horizontal handsaw can be adjusted to different angles for cuts other than 90°. You may cut many types of metal, such as aluminum, steel, brass, or cast iron, with the horizontal bandsaw

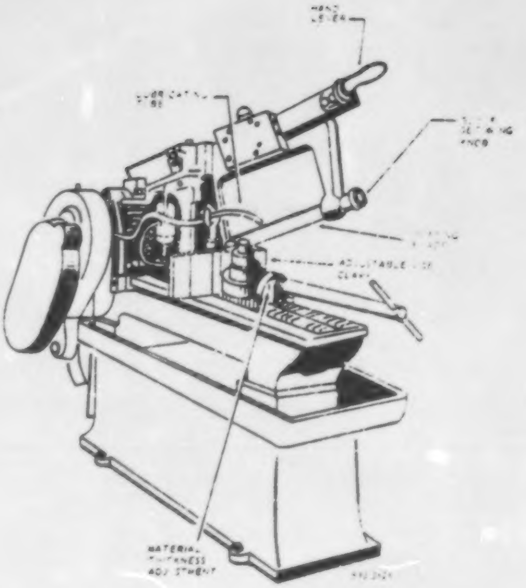


Figure 37. Power hacksaw.

7-8. Cutting blades for the upright and horizontal bandsaws are spot welded at the ends and run continuously on wheels and through guides. If a blade is broken or a new blade installed, the DOALL saw, illustrated in figure 38, is equipped with a butt welder and grinding wheel to smooth the blades after welding so that they will go through the guides. When installing these blades, use the manufacturer's handbook or shop instructions to be sure of proper installation. Both saws are useful but dangerous to an unskilled or careless user. As with other sheet metalworking machines, keep your hands and fingers clear of the cutting blade. Bandsaw operation involves an eye hazard; therefore, you should wear goggles or a face shield. Make certain that you have been properly checked out before attempting to operate these machines.

7-9. **Hole Saws.** Hole saws such as that illustrated in figure 39 are used to cut holes in light gage sheet metal and wood. They may be purchased in sizes up to 4-inch diameter. A ¼-inch electric drill is recommended for hole saw sizes up to 1½ inches and a ½-inch electric drill is recommended for sizes up to 4 inches in diameter. The hole saw is useful for jobs such as venting hot water heaters because most heater vents are 3 inches in diameter. Another use is for cutting holes in fire doors or partitions, since these items are usually covered with light gage metal. When drilling with hole saws, use only

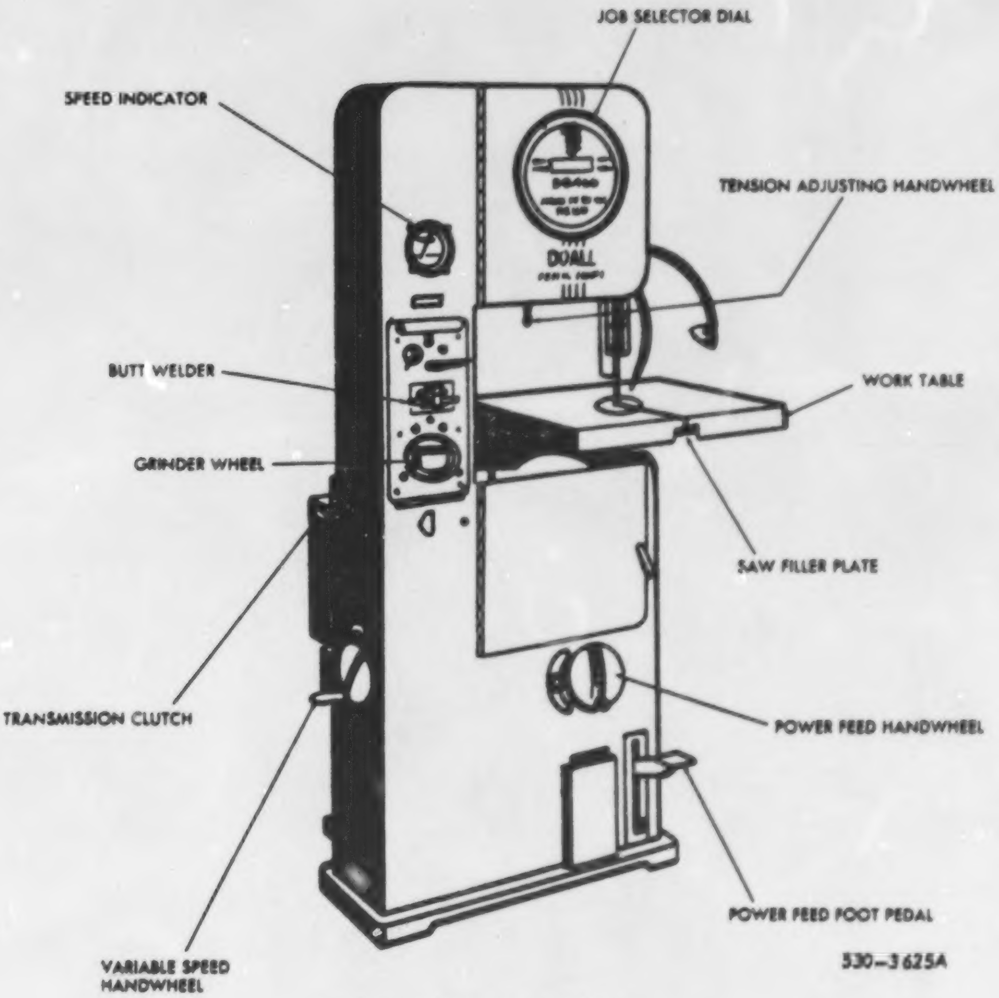

JOB SELECTOR DIAL
SPEED INDICATOR
TENSION ADJUSTING HANDWHEEL
DOALL
BUTT WELDER
WORK TABLE
GRINDER WHEEL
SAW FILLER PLATE
TRANSMISSION CLUTCH
POWER FEED HANDWHEEL
POWER FEED FOOT PEDAL
VARIABLE SPEED HANDWHEEL
530-3625A

Figure 38. Upright bandsaw.

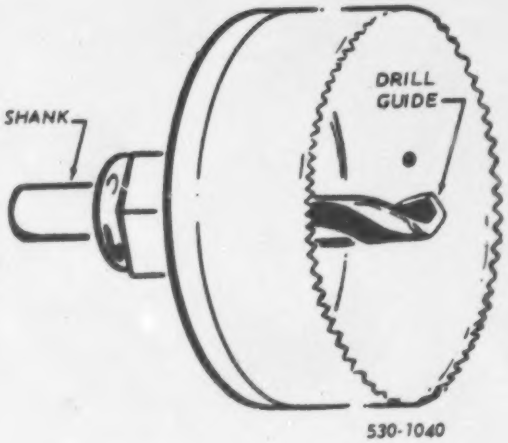

DRILL GUIDE
SHANK
530-1040

Figure 39. Hole saw.

enough pressure to cut evenly. Too much pressure will cause the saw to bind and create excessive strain on the electric drill motor.

7-10. **Circle Cutters.** Circle cutters, like that illustrated in figure 40, are used with slow speed electric drills and drill presses in a similar manner and purpose as hole saws. However the circle cutter differs from the hole saw in that the circle cutter may be adjusted for different sizes and depths of cuts. In figure 40 you can see the setscrew wrench, which is used to loosen and tighten the setscrews or to remove the twist drill. The adjustable arm enables the circle cutter to be used for cutting circles of different sizes, and raising or lowering the cutting blade makes it possible to regulate the depth of the cut. During use, the circle cutter must be held firmly and perpendicular to the material being cut, and the material must be securely held or clamped. Circle cutters are sometimes called fly cutters.

8. Files, Chisels, and Grinders

8-1. In the previous sections we have frequently mentioned the metal burrs that are often produced by cutting equipment. You were cautioned to avoid contact with these burrs, since they can easily cut your hands and fingers or snag your clothing. These rough edges can be removed with files or grinders. Other uses for files and grinders are discussed in this section.

8-2. **Files.** No shop nor individual tool kit is complete without several files. Figure 41 illustrates six shapes of files most used by sheet metalworkers, as follows:

- Flat file—used to file flat surfaces and for other fast cutting operations.
- Mill file—especially adapted for finish filing.
- Triangular, or "three-cornered," file—used in filing internal angles and clearing out corners.
- Square file—most useful in finishing the bottom of slots.
- Round file (or rattail)—used for enlarging round holes.
- Half-round file—used where other files will not fit.

8-3. Files are very useful tools, but their life and usefulness depend a great deal upon the way they are used and maintained. They should be cleaned frequently with a file card or brush and kept separate from other tools to prevent damage to the other tools.

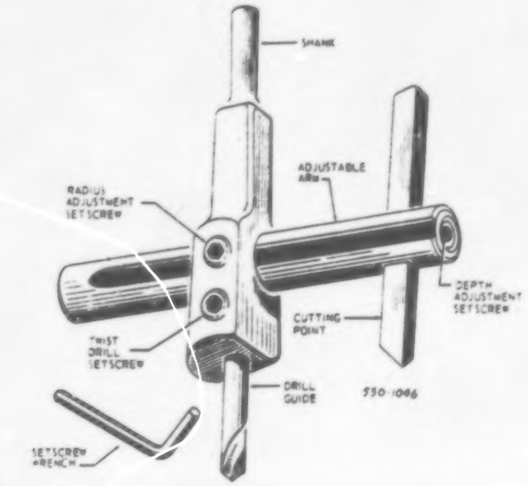


Figure 40. Circle cutter.

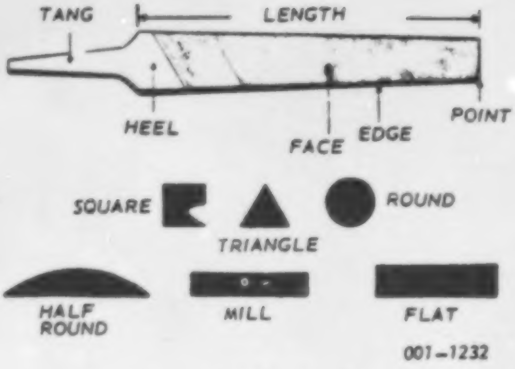


Figure 41. Shapes of files.

8-4. Files are usually made in two types of cuts: single-cut and double-cut, as shown in figure 42. The single-cut file has a single row of teeth extending across the face at an angle from 65° to 85° to the length of the file. The size of the cuts depends on the coarseness of the file. The double-cut file has two rows of teeth which cross each other. For general work, the angle of the first row is from 40° to 45°. The first row is generally referred to as "over-cut"; the second row as "up-cut," the up-cut being somewhat finer and not so deep as the over-cut.

8-5. Single-cut files are recommended for sharpening cutting tools, such as shear and snip blades. Light pressure should be applied to single-cut files to obtain a smooth finish. Double-cut files are used when a rough finish is permissible and heavy pressure may be applied for fast cutting. One of the factors in selecting a file is the composition of the metal to be filed. An example is stainless steel, which is hard and requires a file with a deep up-cut and a fine over-cut.

8-6. **Chisels.** If you can't use snips or a hacksaw for cutting, the cold chisel will probably do the job. Although cold chisels come in a variety of blade shapes, you will most often use the flat blade type, which is illustrated in figure 43. This chisel can be used in restricted areas for such jobs as making a slot or starter hole in sheet metal for snips or shears. Other uses for cold chisels include splitting rusted nuts from bolts and cutting wire, strap iron, small bars, and rods. A cold chisel may be used to cut any metal softer than itself. The size of a cold chisel is identified according to the width of the cutting blade. In sheet metalwork the cold chisels most often used include the ¼-inch, ½-inch, and 1-inch sizes. Cold chisels are usually made of octagonal (eight-sided) tool steel bar stock and are carefully hardened and tempered.

8-7. Keep your chisels sharp and the edges

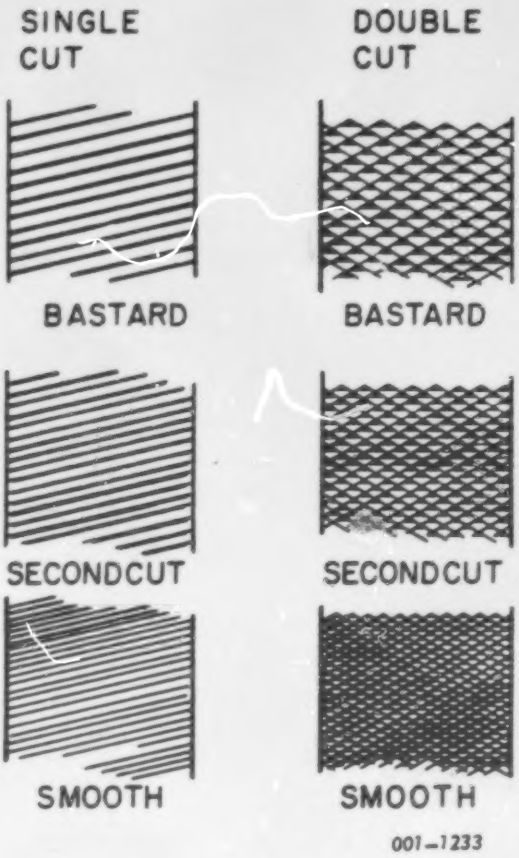


Figure 42. Types of file cuts.

ground at the proper angle (60° to 70°). When sharpening a chisel, hold it against the wheel with very little pressure to avoid overheating. Dip the point in water often enough to keep it cool. Otherwise, the heat generated will "draw" the temper of the steel. If this happens, the cutting edge will become soft and useless until rehardened and tempered.

8-8. Through normal use, the head of the cold chisel will spread out until it looks like a ragged mushroom. This spreadout head is rough and will "ream out" the inside of your hand if the chisel slips. Also, blows of the hammer may break off pieces from the overhanging mushroom and cause injury. Keep the head of the chisel dressed to eliminate these hazards.

8-9. **Grinders.** Electrically driven grinders, such as that illustrated in figure 44, may be attached to work benches or mounted on floor stands. These grinders should be equipped with eyeshields, wheel guards, work rests, power cord with ground, and good abrasive wheels. They normally have medium and fine abrasive wheels—the medium for heavy cuts and the fine for finish work. Bench grinders are usually equipped for grinding twist drills, chisels, and other small jobs. The cooling tank is filled with water so that the object being ground can be kept cool.

8-10. Grinders are very hazardous; therefore you should be careful when operating them. You should not grind on the side of wheels, and you must not use the work rest more than ⅛ inch from the grinding wheel. Even if the grinder is equipped with an eyeshield, you should wear a face shield during operation. When starting a grinder, stand aside until it attains operating speed. This will protect you if one of the wheels is defective and disintegrates. If the grinder chatters or vibrates excessively, something is wrong; turn off the power immediately. When grinding, use only enough pressure to cut the material. Too much pressure will cause undue wear to the wheel and unnecessary heating of the material being ground.

8-11. **Scrapers.** Scrapers are used to scrape paint, grease, or rust from surfaces to be soldered, or they are used to scrape calking compound or other sealants from a joint or seam requiring repair. Figure 45 illustrates a scraper

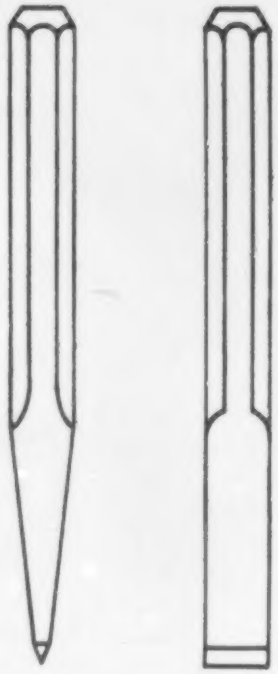


Figure 43. Flat cold chisel.

171

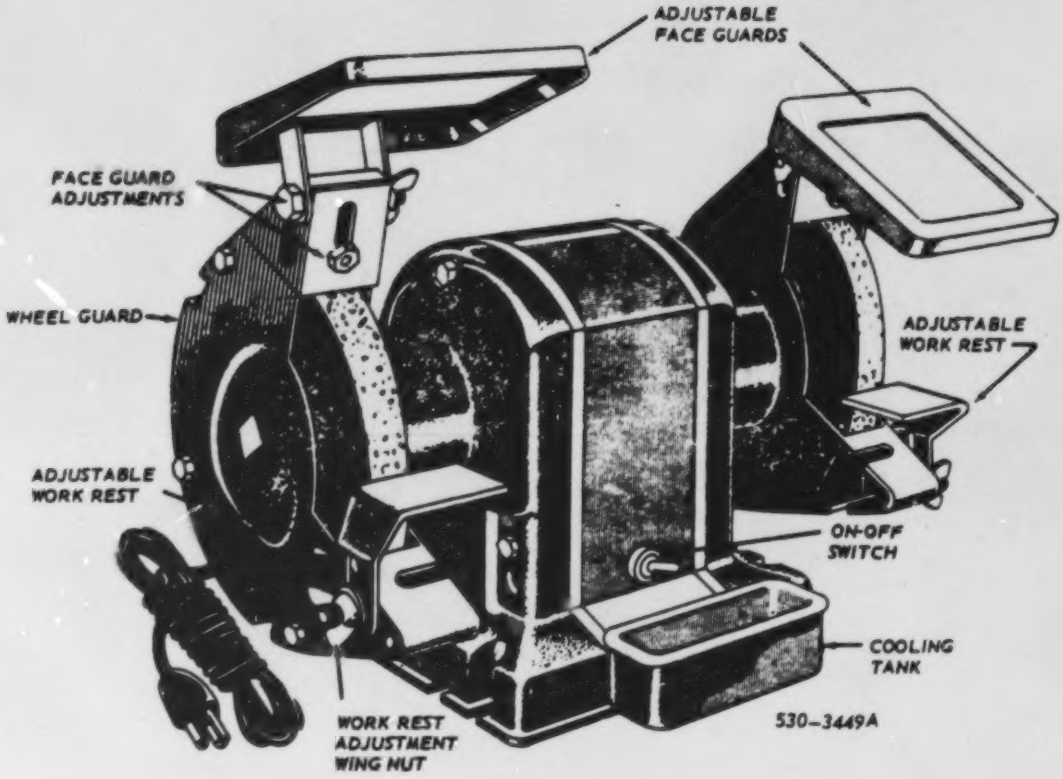

ADJUSTABLE FACE GUARDS
FACE GUARD ADJUSTMENTS
WHEEL GUARD
ADJUSTABLE WORK REST
ADJUSTABLE WORK REST
ON-OFF SWITCH
COOLING TANK
WORK REST ADJUSTMENT WING NUT
530-3449A

Figure 44. Bench grinder.

combined with a wire brush, since the scraper is often used to remove heavy coatings before using a wire brush. You may find a need for a heavier scraper which can be made from a broken 1-inch power saw blade or an old file. The scraping edge is ground to an angle of approximately 45°. You may find it convenient to keep a scraper in your toolbox or stored near the soldering bench.

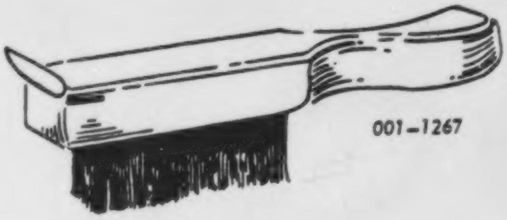


Figure 45. Wire brush with scraper.

CHAPTER 3

Drilling and Punching Equipment

NEARLY ALL fabrication and installation of sheet metal components involve the drilling or punching of holes; therefore, you must be thoroughly familiar with the tools and equipment used and every operation involved. In Chapter 1 of this volume you learned that rivets, screws, and bolts must have holes drilled or punched, and you learned how to use tables which specified the correct sizes.

2. This third chapter concerns the tools and equipment used to drill and punch holes in sheet metal. The drilling equipment includes twist drills, masonry drills, hand drills, portable electric drills, and drill presses. The hole punching equipment includes hand punches and rotary punches. Related equipment which will be discussed includes countersinks, reamers, and rotary files. It is important that you learn the proper use of each of these items also maintenance procedures and safety precautions.

3. The information you gain from this chapter will be applied as you study fabricating, installing, and repairing sheet metal components in Volume 3 of this CDC. Following the completion of on-the-job training, you will frequently use this information as you perform the various work assignments in the sheet metal shop.

9. Drilling Equipment

9-1. It is important for you to use the correct terms when speaking or writing about drilling equipment. For example, the word "drill" when used loosely may cause some confusion in communication. A twist drill is the part that cuts the hole, whereas the hand drill, portable drill (air or electric), or drill press supplies the rotary motion and torque to rotate the twist drill.

9-2. **Twist Drills.** Twist drills may be made of carbon steel or of high-speed alloy steel. Although carbon steel twist drills are satisfactory for general work, high-speed twist drills are recommended for most jobs in sheet metalwork, since they stay sharp longer and do not dull from the heat generated during the drilling operation. If you are drilling holes in hard or thick metal, it is desirable to apply a few drops of cutting oil in the hole for lubrication and prevention of excessive heating. If a cutting oil is used, high-speed twist drills will keep right on cutting, even though they are hot. Excessive heating will also result from using a dull twist drill or from too much or too little pressure on the twist drill. If a high-speed twist drill becomes overheated, it should be allowed to cool slowly. Do not cool an overheated high-speed twist drill in water, oil, or fast moving air, because the metal may crack.

9-3. Twist drill sizes are expressed in terms of numbers, letters, and inches or fractions of inches, as shown in figure 46. The size is stamped on the shank of the twist drill. For example, a $\frac{3}{16}$-inch twist drill, which is often used in sheet metalwork, has a decimal equivalent size of 0.1875 inch. Other tables which can be used for selecting suitable twist drill sizes for rivets, sheet metal screws, and machine screws are located in Chapter 1 of this volume.

9-4. Figure 47 shows a twist drill with the nomenclature of its parts, including the shank, body, heel, flute, and land. A twist drill for most uses will have a lip angle of 59° and a heel angle of 12° to 15°. However a lip angle of 68° is recommended for hard materials, such as stainless steel. Soft metals, such as brass or bronze, can be drilled with a twist drill having a lip angle between 50° to 60°. In all cases of sharpening a twist drill, both cutting edges must have the same lip angle and the same length cutting edge.

9-5. When you are drilling a hole with a twist drill installed in a hand or power drill, the chuck must be tight enough to prevent slippage. The twist drill must make a hole with its center at the exact spot desired; therefore, you should use a center punch to sink a mark deep enough to prevent the twist drill from "walking" away from the center point. (Be careful not to dimple the material by striking the center punch too hard.) Next, secure the work and place the point of the twist drill into the punch mark. After drilling is begun, you must make certain to keep the drill at right angles to the surface of the work through-

Decimal Equivalent of Drill Sizes							
Size	Decimal Equiv.	Size	Decimal Equiv.	Size	Decimal Equiv.	Size	Decimal Equiv.
½	.5000	G	.2610	23	.1540	1/16	.0625
31/64	.4844	F	.2570	24	.1520	53	.0595
15/32	.4687	E-¼	.2500	25	.1495	54	.0550
29/64	.4531	D	.2460	26	.1470	55	.0520
7/16	.4375	C	.2420	27	.1440	3/64	.0469
27/64	.4219	B	.2380	9/64	.1406	56	.0465
Z	.4130	15/64	.2344	28	.1405	57	.0430
13/32	.4062	A	.2340	29	.1360	58	.0420
Y	.4040	1	.2280	30	.1285	59	.0410
X	.3970	2	.2210	⅛	.1250	60	.0400
25/64	.3906	7/32	2187	31	.1200	61	0390
W	.3860	3	.2130	32	.1160	62	.0380
V	.3770	4	.2090	33	.1130	63	.0370
⅜	.3750	5	.2055	34	.1110	64	.0360
U	.3680	6	.2040	35	.1100	65	.0350
23/64	.3594	13/64	.2031	7/64	.1094	66	.0330
T	.3580	7	.2010	36	.1065	67	.0320
S	.3480	8	.1990	37	.1040	1/32	.0313
11/32	.3437	9	.1960	38	.1015	68	.0310
R	.3390	10	.1935	39	.0995	69	.0292
Q	.3320	11	.1910	40	.0980	70	.0280
21/64	.3281	12	.1890	41	.0960	71	.0260
P	3230	3/16	.1875	3/32	.0937	72	.0250
O	.3160	13	1850	42	.0935	73	.0240
5/16	.3125	14	.1820	43	.0890	74	.0225
N	.3020	15	.1800	44	.0860	75	.0210
19/64	.2969	16	.1770	45	.0820	76	.0200
M	.2950	17	.1730	46	.0810	77	.0180
L	.2900	11/64	.1719	47	.0785	78	.0160
9/32	2812	18	.1695	5/64	.0781	1/64	.0156
K	.2810	19	.1660	48	.0760	79	.0145
J	.2770	20	.1610	49	.0730	80	.0135
I	.2720	21	.1590	50	.0700		
H	.2660	22	.1570	51	.0670		
17/64	.2656	5/32	.1562	52	.0635		

530–2515

Figure 46. Twist drill sizes.

out the operation. You should ease the pressure the instant the twist drill breaks through the material but continue drilling until the hole is finished. Be sure to follow appropriate procedures to keep the twist drill from overheating.

9-6. **Masonry Drills.** Several types of masonry drills are available for drilling holes in concrete, brick, and cinder block. Holes are needed when attaching sheet metalwork, such as downspouting, duct work, and metal awnings. One type of masonry drill is the star drill (not illustrated) which somewhat resembles a chisel except that the cutting tip forms a cross. Star drills are available in various sizes and are driven by hand with a heavy ball peen hammer. Another type of masonry drill, which is illustrated in figure 48, is designed to fit in the chuck of portable power

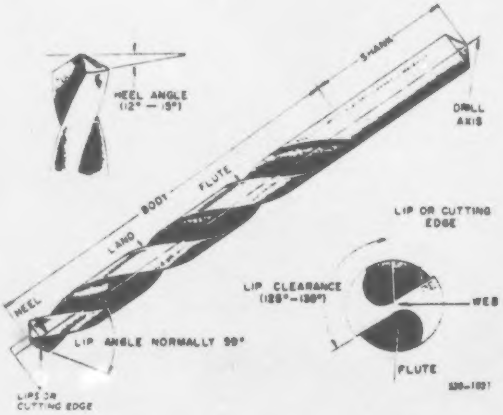
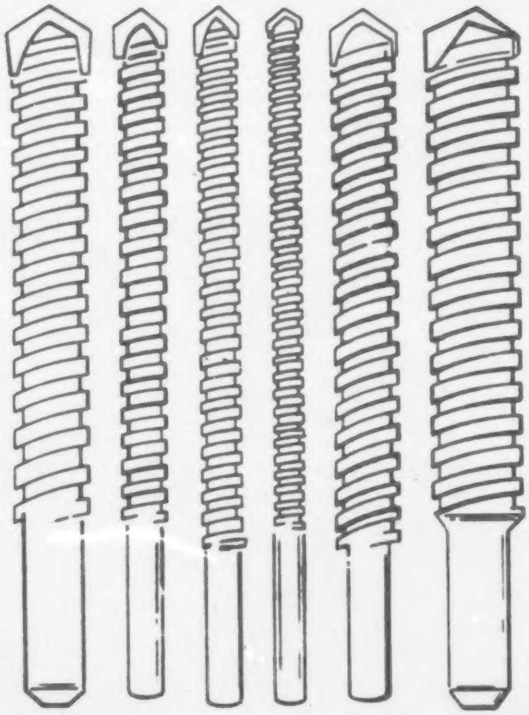


Figure 47. Twist drill nomenclature.



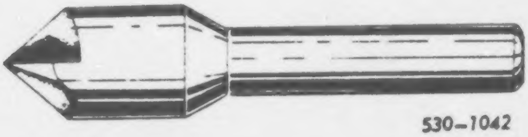
530–1041

Figure 48. Masonry drills.

drills. These masonry drills have tungsten-carbide cutting tips and are available in sizes ¼ inch to ¾ inch. A ½-inch portable drill should be used with masonary drills that are ⅜ inch and larger.

9-7. **Countersinks.** Countersinks are used to bevel edges of holes so that rivets or bolts with countersunk heads can be inserted. This allows the rivet or bolt heads to be flush with the surface of the metal. Figure 49 shows a countersink, which can be used with hand or power drills. These countersinks are available in various bevel angles, which should match the bevel of the rivet or bolt to be installed.

9-8. **Hand Drills.** Hand drills are used to drill holes in light gage sheet metal, and the chuck will normally accommodate a twist drill up to ¼-inch diameter. Hand drills are often used on jobs where only one or two holes are to be drilled, and the holes can be drilled in less time than it would take to install a power cable for an electric drill. Also there will be times when holes must be drilled at locations where the power cable cannot reach the job.



530–1042

Figure 49. Countersink.

9-9. **Portable Electric Drills.** Portable drills are manufactured in several sizes which include ¼, ⅜, and ½ inch, as illustrated in figure 50. The ¼-inch drill is used extensively when drilling holes for rivets, sheet metal screws, and machine screws. A ⅜- or ½-inch drill should be used to drill holes larger than ¼ inch. Portable electric drills will often be used on jobs away from the shop, so be sure that an adequate electrical ground connection is made before beginning the drilling operation.

9-10. When using a portable electric drill, be sure the twist drill (or masonry drill) is firmly tightened in the geared chuck of the drill to prevent the twist drill from turning in the chuck, which may damage the shank of the twist drill. This is done by first tightening the chuck hand-tight, then by inserting the chuck key and tightening in each of the three holes. Do not over-tighten with the chuck key, because the chuck threads can be damaged.

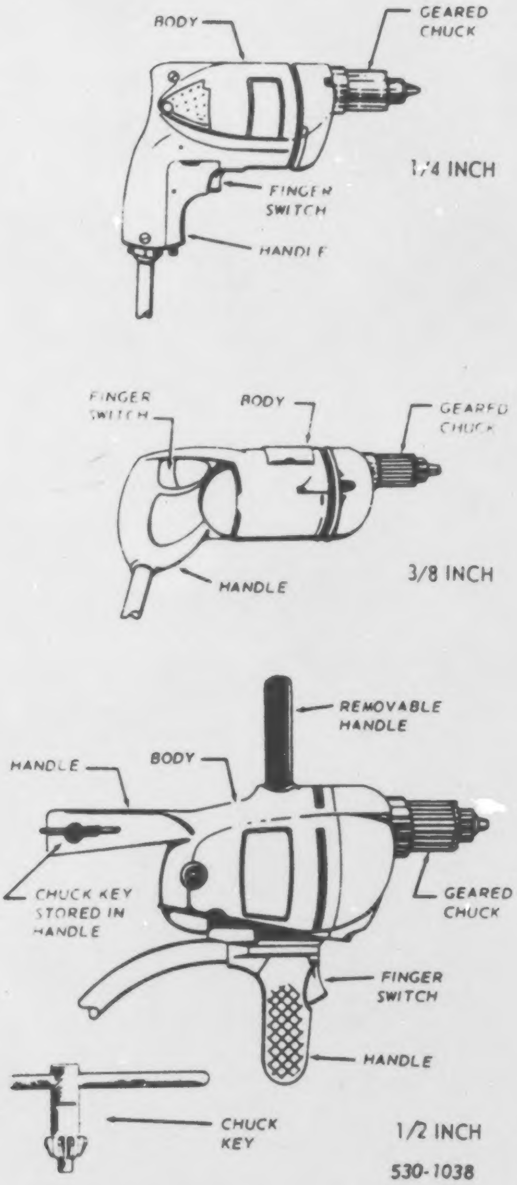
9-11. When using the portable power drill, hold it firmly and place a backup block of wood under the hole location to add support to the metal. Insert the twist drill in the chuck and test it for trueness and vibration. You may check the trueness visibly by running the motor freely. Do not use a twist drill that wobbles or is slightly bent, because such a condition will cause enlarged holes. Always hold the drill at right angles to the work, regardless of the position or curvature. Tilting the drill at any time when drilling into or withdrawing from the material may cause elongation (egg shape) of the hole.

9-12. When drilling through sheet metal, small burrs are found around the edge of the hole. You must remove these burrs to prevent scratching and to allow rivets or bolts to fit snugly. Burrs may be removed with a countersink, a reamer, or a twist drill larger than the hole. If any of these is used to remove burrs, it should be rotated by hand.

9-13. **Drill Press.** The drill press is a precision machine used for drilling holes that require a high degree of accuracy. It serves as an accurate means of locating and maintaining the direction of a hole that is to be drilled, and it provides the operator with a feed control lever to regulate the drilling pressure and make the task of feeding the drill into the material easier. A variety of drill presses are available; however, the most common type is the ordinary upright drill press, shown in figure 51.

9-14. When using a drill press, adjust the height of the working table to accommodate the height and thickness of the part to be drilled;

175



BODY
GEARED CHUCK
1/4 INCH
FINGER SWITCH
HANDLE
FINGER SWITCH
BODY
GEARED CHUCK
HANDLE
3/8 INCH
REMOVABLE HANDLE
HANDLE
BODY
CHUCK KEY STORED IN HANDLE
GEARED CHUCK
FINGER SWITCH
HANDLE
CHUCK KEY
1/2 INCH
530-1038

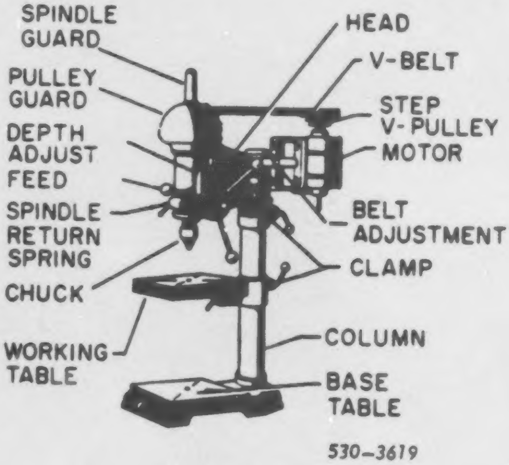
Figure 50. Portable electric drills.

then clamp the material into position so that the center punch mark is directly in line with the twist drill. Material or parts that are not properly clamped may bind on the drill and start spinning, which can possibly cause the loss of fingers or hands or cause serious cuts to the operator's arms or body. Always make sure the part drilled is properly clamped to the drill press table before starting drilling operations. You must wear goggles, safety glasses, or a face shield in accordance with the safety rules of your shop.

9-15. Most drill presses are equipped with gears or multistep pulleys to provide a means of increasing or decreasing the speed of the spindle. Prior to changing the speed, you should stop a drill press. The drill press shown in figure 51 is illustrated with the belt guard removed. The drill press can be adjusted for different spindle speeds by changing the V-belt to different steps on the V-pulleys. Be sure to stop the motor before moving the belt from one step to another, and don't forget to check the belt adjustment before operating the drill press.

9-16. Continued use of too heavy a feed or too fast a speed will make the machine labor and may cause twist drill breakage or may damage the machine. Speed of the chuck and rate of feed through the material vary depending on the material you are drilling. You should check the manufacturer's handbook or the technical manual for information concerning the feed and speed recommended for various drilling operations. When drilling hard metal or steels, use a cutting oil to cool and prevent dulling the twist drill. With proper feed and speed, the drill will usually produce a spiraled shaving; however, granular cuttings will be produced when drilling cast iron or other porous materials. To prevent binding or breakage, always reduce feed or pressure just before going through the metal.

9-17. Preventive maintenance procedures for a drill press consist mainly of keeping it cleaned, adequately lubricated, and properly adjusted. Like other machines in the sheet metal shop the drill press should have a maintenance record folder, which will specify the items to be inspected and serviced, the intervals of inspection, and a place to record and initial the maintenance accomplished. A drill press such as that illustrated in figure 51 should be inspected.



SPINDLE GUARD
HEAD
V-BELT
PULLEY GUARD
STEP V-PULLEY
DEPTH ADJUST
MOTOR
FEED
SPINDLE RETURN SPRING
BELT ADJUSTMENT
CLAMP
CHUCK
WORKING TABLE
COLUMN
BASE TABLE
530–3619

Figure 51. Drill press.

182

Be sure that the belt guard is installed, that the V-belt has the correct tension, that the machine is clean, and that all parts operate and are serviceable. The motor of the drill press illustrated has sealed bearings and does not require oiling; however, the spindle and the depth adjustment feed handle have oil cups for lubrication. Lubricate the support column with an oiled rag to prevent corrosion and to allow the working table and head assembly to move up and down freely. Usually the V-belts on this type of equipment are adjusted to have a deflection of approximately ½ inch. Improper tension could cause a belt to break or fail to turn the spindle. To adjust the belt tension, loosen the belt adjustment nut, then tighten it after the proper distance between the pulleys has been obtained.

10. Punching Equipment

10-1. There are several types of punches which you will use in sheet metalwork, including those for marking metal before drilling, for removing pins, for aligning holes, and for piercing holes. Each punch is designed for a specific job. Hand punches that are driven with a hammer which you use in sheet metalwork include the center punch, prick punch, starting punch, drift punch, pin punch, and hollow punch. Lever type punches that you will also use are the Whitney punch, iron hand lever punch, and rotary punch.

10-2. **Hand Punches.** There are many types of hand punches that can be used in sheet metal shops; however, the punches illustrated in figure 52 are used more often than others. The heads and points should be kept in good condition in the same manner as chisels. The *center punch* is used to make a small depression in metal prior to drilling or punching. This depression prevents the twist drill from "walking" during the drilling operation. The *prick punch* is used to establish location points when laying out patterns on sheet metal. The *starting punch* is tapered for strength, has a blunt tip, and is used to loosen tight fitting pins that are removed from a hole. A *drift punch (taper punch)* is also used to loosen tight fitting pins, although its slender taper is not as strong as the starting punch. The drift punch is often used to align holes in two pieces of metal prior to installing screws, bolts, or rivets. The *pin punch* has no taper; it is used to drive out rivets which have had the heads drilled off and to drive pins out of holes too deep for the starting punch or drift punch. The starting punch, drift punch, and pin punch are blunt end punches and are sometimes called solid punches. *Hollow punches* when used with suitable backup material are used to pierce holes in thin metal.

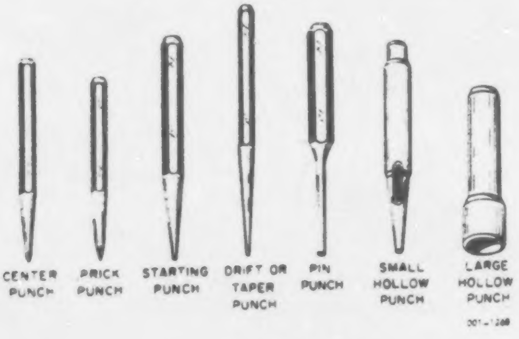


Figure 52. Hand punches.

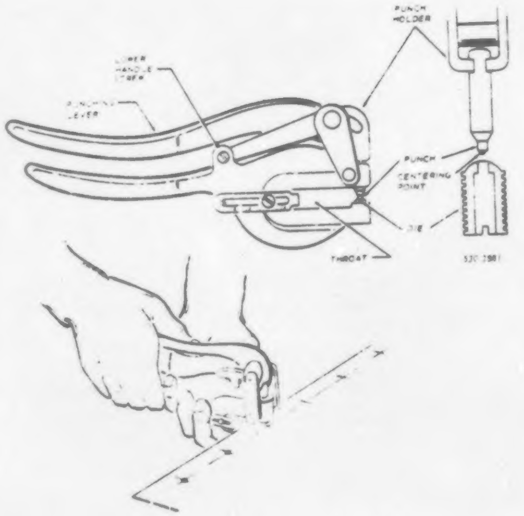


Figure 53. Whitney punch.

10-3. **Whitney Punch and Iron Hand Lever Punch.** The Whitney punch and the iron hand lever punch have interchangeable dies for piercing holes in metal. The Whitney punch, shown in figure 53, is used to punch light gage metal and is available with dies ranging in size from 1/16 to 9/32 inch. When making holes in exact locations, set the centering point in the center punch mark. The iron hand lever punch is similar to the Whitney punch except that it has longer handles; it is available with dies ranging in size from 3/32 to ½ inch. Both punches have short throats and are used when hole locations are near the edge of the material. You will find that both punches will pierce holes much faster in light gage metal than it is possible to do so with twist drills. When changing punches and dies, be sure to match the sizes. Too large a punch for a die will damage the cutting edges, and too small a punch will pierce the hole but dimple the material.

10-4. **Rotary Punch.** This large punch press is used in the sheet metal shop to punch holes in metal parts such as baffle plates and tops for drain tables. It can also be used for cutting radiuses in corners and for making washers. The rotary punch press shown in figure 54 is found in many Air Force sheet metal shops. It is composed of two cylindrical turrets, one mounted over the other and supported by the frame. Both turrets are synchronized so that they rotate together, and the index pins maintain correct alignment at all times. To release the index pins from their locking position, the lever, which is located on the right side of the machine, is rotated through a 180° arc. This action will withdraw the index pins from the tapered holes and allow you to turn the turrets to any size punch desired.

10-5. To operate this rotary punch, place the metal between the die and punch. Then the hand lever, which is on the top right side of the machine, is pulled towards you. This will force the punch through the metal. When the lever is returned to its original position, the metal will be stripped off the punch.

10-6. Stamped on the front of each dieholder is the diameter of the punch and its maximum capacity for punching mild steel. Each punch is made with a point which can be placed in the center punch mark. This point will assure you the definite location to be pierced.

10-7. To accurately align the punch and die, you must determine where the adjustment is necessary by punching through several thicknesses of stiff paper. This will show which side of the die has the greatest clearance. If the cut is uneven, loosen the lockscrews and tap the die in the opposite direction. When the paper is cut evenly all around, tighten the punch securely with the lockscrews. The lockscrews are located between each set of dies.

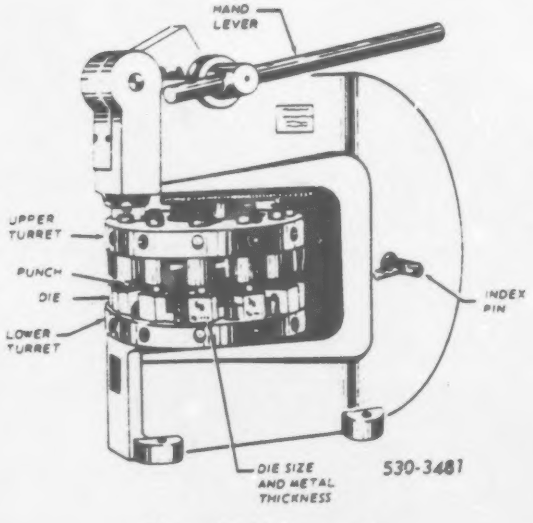


Figure 54. Rotary punch.

10-8. Preventive maintenance for the rotary punch consists mainly of keeping it cleaned, adequately lubricated, and properly adjusted. At intervals specified on the maintenance record folder, the rotary punch, such as illustrated in figure 54, is inspected to see that the index pin works freely and locks the upper and lower turrets easily. If necessary, clean and oil the index pin and aligning holes in the turrets. Next, inspect each punch and die to see if it lowers and raises freely when the hand lever is pulled forward. Cleaning and oiling are necessary for any that stick. To accomplish a thorough cleaning, you must remove a sticking punch. Then clean the punch and its sleeve and lightly coat them with oil before reassembly. Next, inspect the hand lever and connecting linkage for cleanliness and freedom of operation; if necessary, clean and oil the moving parts. Now, inspect each punch for proper alignment with its corresponding die. Do this as mentioned in paragraph 10-7, by punching several thicknesses of stiff paper. Finally, wipe off all excess oil, clean all painted surfaces with a dry rag or a rag moistened with soap and water, and wipe all unpainted surfaces with a slightly oiled rag. The final step is to make the appropriate entries in the maintenance record folder.

10-9. The principal safety precaution to observe when operating the rotary punch press is to keep your fingers away from the punch and die and to return the hand lever to the full up position after each operation has been completed. Be sure the operating instructions and safety precautions for the rotary punch are legible and posted in the most obvious location.

11. Reamers and Rotary Files

11-1. **Reamers.** Tapered reamers such as those illustrated in figure 55 have several uses in sheet metalwork. You will find them useful for enlarging holes and removing burrs. These reamers have tapered spiral flutes with cutting edges somewhat similar to the countersink you saw in figure 49. One of the reamers illustrated in figure 55 is turned by hand, and two are used with a carpenter's brace. The size and shape to select for enlarging holes or removing burrs from sheet metal will be determined by the diameter of the holes. Tapered reamers are frequently used to ream the ends of tubing or pipe which have been cut. In Chapter 1 you learned that burrs should be removed from around holes prior to installing rivets. Removing burrs is also a good safety practice because they are sharp and may snag flesh and clothing. When using reamers to en-

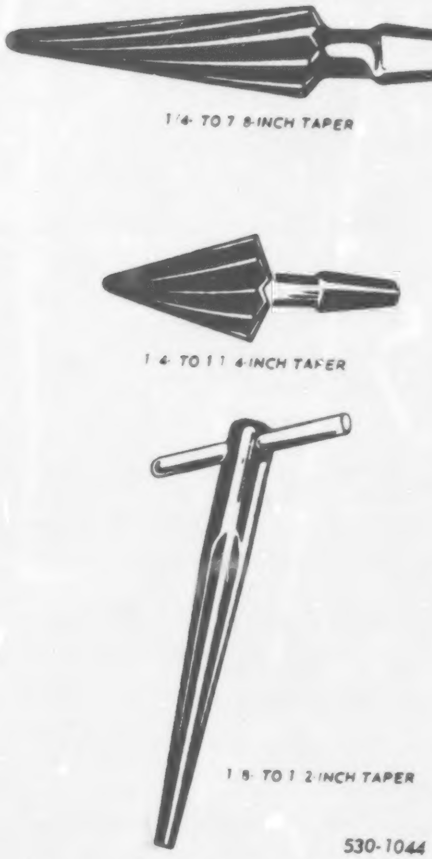

1/4- TO 7/8-INCH TAPER
1/4- TO 1 1/4-INCH TAPER
1/8- TO 1/2-INCH TAPER
530-1044

Figure 55. Reamers.

large holes or to remove burrs, be careful not to use too much force, because it will cause the reamer to take too large a "bite" and remove too much metal which will result in a hole that is oversized or beveled.

11-2. **Rotary Files.** Rotary files such as those illustrated in figure 56 have 1/4-inch diameter shanks which can be "chucked" in a hand drill, a portable electric drill, or a drill press. Rotary files with spiral cutting flutes, which are smaller than the spiral flutes of reamers, are used more often to ream or enlarge holes than to remove burrs. Although in most cases you will use a twist drill to enlarge a hole in sheet metal, there will be occasions when it is desirable to use a rotary file instead. Selection of the size and shape of rotary file to use will depend upon the job. For example, the rotary files illustrated in figure 56 can be used to ream holes, to elongate slots, and to file irregular shaped edges.

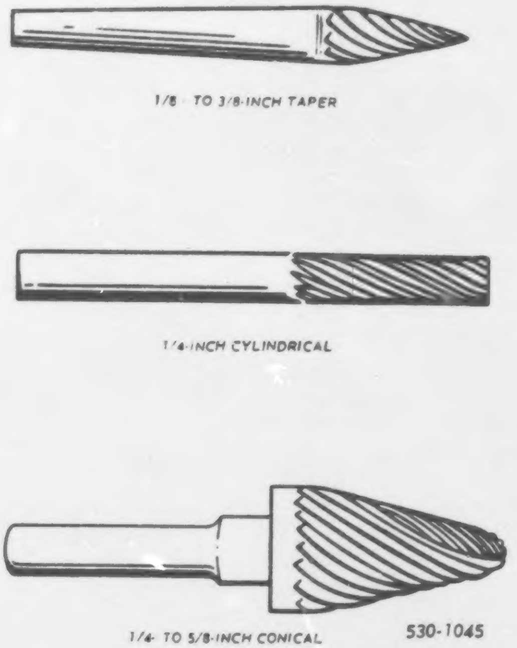

1/8- TO 3/8-INCH TAPER
1/4-INCH CYLINDRICAL
1/4- TO 5/8-INCH CONICAL
530-1045

Figure 56. Rotary files.

Folding, Forming, and Seaming Equipment

IN THIS CHAPTER you will study pieces of equipment which are used to fold, form, and seam sheet metal; some of which are handtools, and others are machines. The straight line forming machines include such equipment as the bar folder, cornice brake, and box and pan brake, which are capable of making straight line folds or bends in sheet metal. Rotary forming equipment includes slip roll forming machines and a variety of rotary machines. Handtools used when forming sheet metal include such items as dollies, form blocks, vises, stakes, seamers, groovers, and various kinds of hammers and mallets. In this chapter you will also study safety precautions; maintenance tips; and the adjustment and use of folding, forming, and seaming equipment.

2. You will want to become well qualified in the use of this equipment, because the strength and general appearance of a completed job will be greatly affected. For example, suppose you have made a perfect flat pattern for a component, such as a rectangle to round transition. The next step is fabrication, which includes cutting, forming, and seaming. And if you are to fabricate a component correctly, it will be necessary to use each machine correctly. In Chapter 2 we discussed cutting equipment; now we will discuss the specialized equipment used to fold, form, and seam sheet metal.

12. Safety and Maintenance Procedures

12-1. General safety procedures to follow when using folding, forming, and seaming equipment include such practices as keeping hands, fingers, and clothing clear of clamping devices, folding blades, bending leafs, and forming rollers. Make sure that materials and personnel do not interfere with proper operation of handles and levers of the machines. Specific safety procedures are discussed in the following sections along with the individual machines.

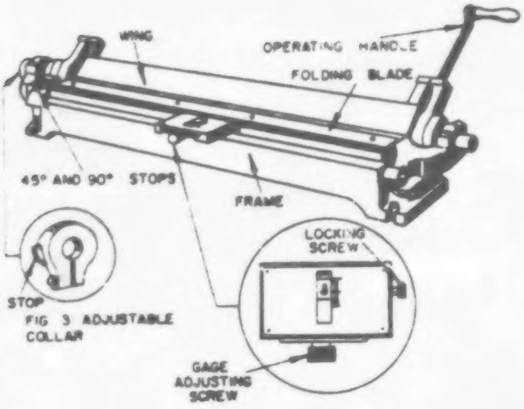
12-2. General maintenance requirements for folding, forming, and seaming equipment include keeping machines lubricated, cleaned, and properly adjusted for the gage of metal to be formed. These machines should not be overloaded by exceeding the recommended capacity. Like other large machines in the sheet metal shop, each piece of folding, forming, and seaming equipment should have a maintenance record folder, which will specify the items to be inspected and serviced, the intervals of inspection, and a place to record and initial the maintenance completed. Specific maintenance procedures are discussed in the following sections along with the individual machines.

13. Folding Equipment

13-1. One of the most frequent and common operations in sheet metalwork is that of folding metal, and it is practically impossible to make these folds accurately without the aid of machinery. Folding machines that we will discuss include the bar folder, cornice brake, box and pan brake, and brace and wire bender. The bar folder is used when the width of the fold to be made falls within the fold capacity of the machine. However, if the width of the fold is too great for the folder, the cornice brake is used. The box and pan brake is used to fold boxes and pans, as its name implies. The brace and wire bender is used to bend wire, round rod, and narrow widths of flat plate.

13-2. **Bar Folder.** The bar folder, shown in figure 57, is designed to make bends and folds along the edges of sheets from 0° to 165° up to and including 43 inches in width. The thickness capacity of the bar folder illustrated is 20-gage material. This is the machine generally found in most sheet metal shops. The width of the folds, or gaging range, is usually from $\frac{3}{32}$ to 1 inch, depending on the thickness of the material; the thinner the gage, the smaller the fold. The maximum diameter for wire edged folds is $\frac{1}{4}$ inch. The bar folder is best suited for forming small hems (double or single), right-angle folds, rounded folds, and acute folds (less than 90°).

13-3. The bar folder is adjusted for different thicknesses of material by adjusting the wing



530-3457

Figure 57. Bar folder.

pressure screws at each end of the folder. These adjustment screws are not visible in figure 57, but each consists of a threaded shaft with an adjusting nut and a locking nut which are tightened with a wrench to increase or decrease the distance between the wing and folding blade. After this adjustment has been made, the piece of metal is placed in the folder and the operating handle raised until the small roller rests on the cam. The wing is held in this position and the adjusting screw and locknut are set so that the sheet metal is clamped securely, and evenly, the full length of the folding blade. After the folder has been adjusted, each end of the machine is tested separately by folding a small piece of metal. Care should be taken not to adjust the bar folder to the extent that clamping pressure is excessive because too much pressure will cause damage to the machine. Excessive pressure is easily detected, because in that condition the machine does not operate freely.

13-4. The width of the fold is controlled by the gage adjusting screw (shown in fig. 57), which can be turned either clockwise or counterclockwise. This screw moves the slide and gage bar back and forth for the desired fold. The gage bar is under the folding blade and is not visible when you stand in front of the folder. Although the gage is graduated in fractions of an inch, a 6-inch rule is used for an accurate measurement by sliding the rule between the jaw and blade and holding it against the gage bar. After the measurement has been made, the gage is locked in place by tightening the lock screw, which is on the right side of the gage.

13-5. It is possible to make both sharp and round folds with this machine. Before the machine is adjusted, the wing must be perpendicular to the folding blade. Then a wedge which supports the wing must be properly adjusted by using the wedge adjusting knob located in the center back side of the folding bar. To make a sharp bend, the wedge is set in such a manner that the wing will stay in the same position through a cycle of operation. To make a round fold, the wedge is adjusted so that the wing falls back when it starts to swing.

13-6. There are two positive stops on the folder—one for 45° bends and the other for 90° bends. However, the movement can be adjusted to *any* degree of bend within the capacity of the machine by using the adjustable collar shown in figure 57.

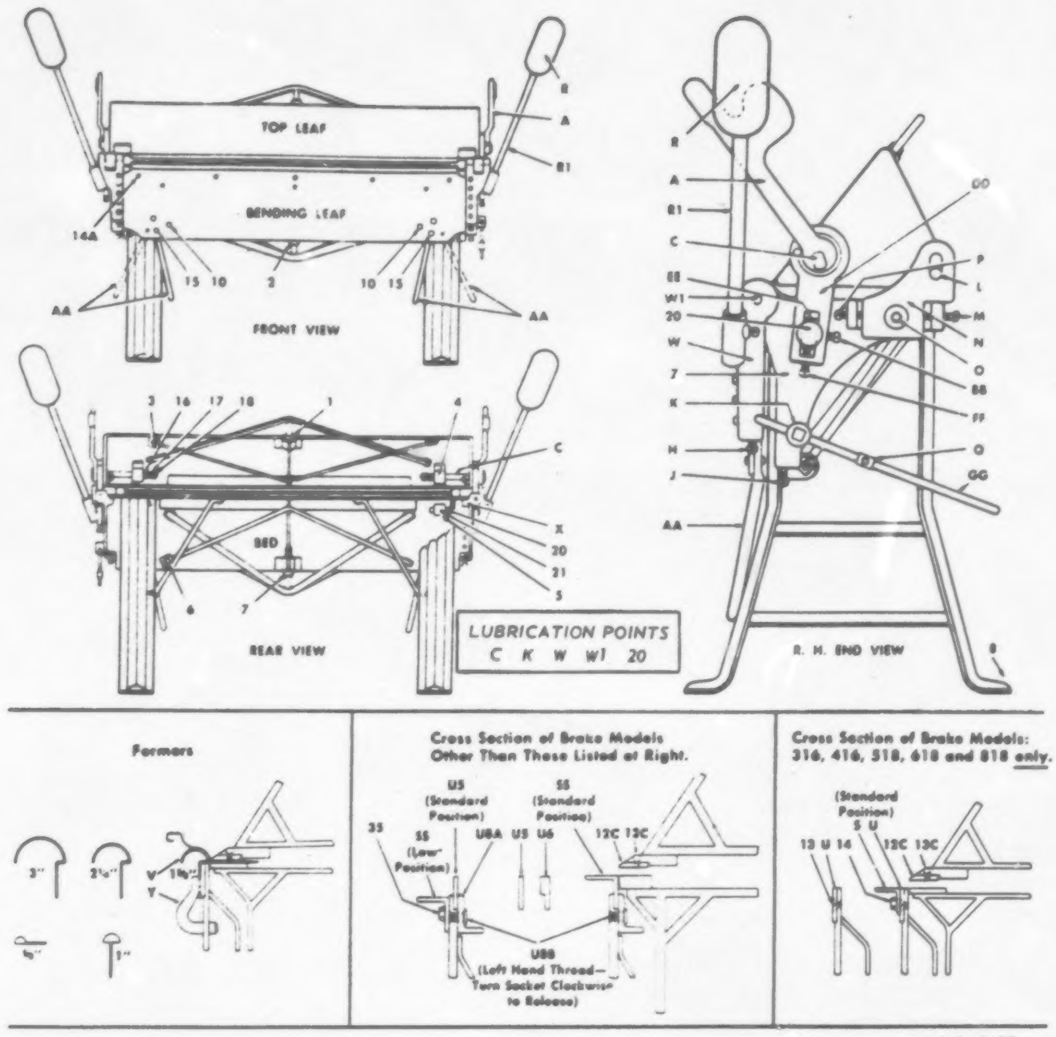
13-7. After the bar folder has been correctly adjusted, the metal is inserted between the folding blade and wing. When the metal is held firmly against the gage and the operating handle pulled forward, the wing will automatically raise and hold the metal until the desired bend is made. This safety feature allows the left hand to be clear of the folding blade. When the handle has been returned to its original position, the wing and blade will return to their original positions and release the metal.

13-8. **Cornice Brake.** The cornice brake, illustrated in figure 58, is a type of folding machine that has a much greater range than most folders. The cornice brake not only forms locks and bends, but it can do complicated jobs, such as forming complex seams and shapes, because of its construction. It also forms square, round, and ogee bends. It can be used for many jobs, such as forming ducts, gutters, transitions, flashing, and gravel guards as well as joints, seams, and locks. For example, a Pittsburg lock can be formed very easily with the cornice brake if a Pittsburg machine is not available.

13-9. To get the most out of a cornice brake, it is necessary to know how to adjust it for various operations. These adjustments are very important because they save time and improve the quality of the work.

13-10. The cornice brake must be level on the floor to prevent creeping of the top leaf when metal is clamped between the top leaf and the bed. If the top leaf creeps, screw P and the screw O should be checked; both are shown in figure 58. If adjusting these screws does not remedy the creeping, a wedge of wood or similar material is placed under the rear leg on the side that creeps. The wedge should be forced until the creeping is eliminated then replaced with a permanent block of the proper height.

13-11. Next, the bending leaf is checked when it is in the down position. The edge of this leaf should be $1/64$ inch below the bed edge at the ends and $1/32$ inch below the bed edge at the


TOP LEAF
BENDING LEAF
FRONT VIEW
REAR VIEW
BED
R. H. END VIEW
LUBRICATION POINTS
C K W W1 20
R
A
R1
C
DD
EE
W1
20
W
7
K
H
J
AA
P
L
M
N
O
BB
FF
Q
GG
14A
15
10
2
T
3
16
17
18
1
4
X
21
S
6
8
Formers
3"
2¼"
V
Y
1"
Cross Section of Brake Models Other Than Those Listed at Right.
35
US (Standard Position)
SS (Low Position)
UBA
U5
U6
SS (Standard Position)
12C
13C
UBB (Left Hand Thread—Turn Socket Clockwise to Release)
Cross Section of Brake Models: 316, 416, 518, 618 and 818 only.
(Standard Position)
S U
13
U
14
12C
13C
530-3432

A—Clamping Handle
AA—Bending Leaf Handle
BB—Link Set Screw
C—Top Shaft
DD—Link
EE—Link Adj. Block
FF—Link Adj. Screw
GG—Stop Gauge Rod
H—Bending Leaf Hinge Adj. Screw
J—Bed End Adj. Screw
K—Stop Gauge Guide
L—Slot Casting Pin
M—Slot Casting Adj. Screw
N—Slot Casting
O—Slot Casting Lock Screw
P—Slot Casting Adj. Screw
Q—Adjustable Stop
R—Balance Weight
R1—Balance Weight Rod
S, SS—Bending Leaf Angle Bar
U—Bending Leaf (¼") Bar
US—Bending Leaf (¼") Bar
U6—Bending Leaf (½") Bar
UBA—Bending Leaf Bar Holder
UBB—Bar Holder Screw
V—Formers (Specify Sizes)
X—Bed Adj. Screw
W—Bending Leaf Hinge
W1—Bending Leaf Hinge Pin
Y—Former Clamp
Z—Bed End Housing
2—Bending Leaf Adj. Bolt
7—Bed Adj. Bolt
10—Bending Leaf Tension Bolt
12C—Top Nose Bar
13C—Top Nose Bar Screw
14—(S) Angle Bar Screw
15—Bending Leaf Handle Screw
16—Clamping Handle Spring
17—Clamping Handle Washer
18—Clamping Handle Nut
20—Bottom Shaft
21—Bottom Shaft Set Screw
35—(SS) Angle Bar Screw

Figure 58. Cornice brake.

center. To obtain and maintain this alignment, the following adjustments are necessary:

- Leaf ends adjusted with screws H (right-hand end view).
- Leaf center adjusted with bolt 2 (front view).
- Bed ends adjusted with screws J (right-hand end view).
- Bed center adjusted with bolt 7 (rear view).

13-12. When bending various thicknesses of sheet metal with the cornice brake, the top leaf should be moved back at the bending edge. If the material is within four gages of capacity of the machine, the top leaf should be moved back twice the thickness of the material. When sharp bends are made on lightweight metal, the top leaf should be moved forward. The top leaf adjustment is made as follows:

- Screws O are loosened (shown in right-hand end view).
- The top leaf is moved forward or backward by adjusting screw M or P (shown in right-hand end view); these screws have right-hand threads.
- Once the correct adjustment is made, screws O are tightened.

13-13. The clamping pressure should be tight enough to hold the metal in place while the bend is made. Different gages of metal require different adjustments; therefore, you must realize that every gage of metal will have its own adjustment. Remember, the pressure should be equal on both ends of the machine. This clamping pressure can be changed by adjusting the link blocks (EE in right-hand view of fig. 58). To do this job:

- Screws BB which hold link adjustment blocks EE are loosened.
- Blocks EE are adjusted to thickness of metal with screws FF.
- Adjustment blocks EE are locked in position with screws BB.
- A test strip is used to make sure the machine is correctly adjusted.

13-14. After the cornice brake has been correctly adjusted, the metal is placed on the bed beneath the top leaf. The top leaf is partially lowered by pulling the clamping handle (A in fig. 58) forward. The scribed break line on the metal (or prick points) is aligned with the nose bar (12C) on the top leaf; then the clamping handle is pulled until the metal is firmly clamped. To make the fold, the bending leaf handle (AA) is pulled forward and upward, which swings the bending leaf forward and upward as it pivots on the bending leaf hinge pin (W1). As the bending leaf swings up, the balance weights (R) move backward, acting as counterbalance weights for easier manual operation. When the desired angle of bend is reached, the bending leaf is lowered by movement of its handle or the balance weight. When the clamping pressure is released, the metal can be removed.

13-15. The capacities of machines like the one illustrated in figure 58 range from 22- to 16-gage sheet metal, and bending lengths range from 3 to 12 feet. However, the bending capacity of the cornice brake is determined by the bending edge thickness of the various bending leaf bars (S, SS, U, U5, and U6 in fig. 58). Bending leaf angle bars S and SS permit a smooth 1-inch flange to be made in a piece of material that is within the capacity of the cornice brake. Some pressure is released on the bending leaf bar identified as U when the S or SS bar is installed.

13-16. In figure 58, bending leaf bar U6 is a ½-inch bar for the bending leaf. When U6 is used to make flanges, the capacity of the brake is reduced by 4 gages. For example, if the cornice brake is rated at 16 gage, the capacity with a ½-inch U6 bending leaf bar will be 20 gage.

13-17. Suppose you are using the cornice brake to make small offset bends ¼-inch wide. If your brake is like model 316 illustrated in figure 58, the bending leaf bar identified as U should be removed. If your brake is a model other than those like model 316, the ¼-inch offset can be made by installing bending leaf bar U5. In both of these situations the rated capacity of the cornice brake is reduced 7 gages. For example, a cornice brake rated at 16 gage is reduced to 24-gage capacity. You should remember this capacity change, because the bending leaf can be easily warped if the rated capacity is exceeded. Duplicate bends can be made with any of the models of brakes that you may have in your shop by setting the adjustable stop, O, for the desired angle.

13-18. There are occasions when you will find that the material will bend excessively or that it will bend further on one end of the brake than on the other. To correct either condition:

- Screws O (shown in right-hand end view) are loosened.
- The top leaf is readjusted with screws M and P.
- Screws O are again tightened.

13-19. If the bending leaf becomes bowed after repeated heavy use, both bolts (10, front view) are tightened until the center is brought in line. This line should be straight and should be checked with a straight edge.

13-20. Molds or formers, as illustrated in figure 58, can be obtained in half-round sizes, such as ⅝, 1, 1⅝, 2¼, and 3 inches, and are used most often to make gutters. These formers are attached to the brake with clamps Y; usually three to five clamps are used.

13-21. To attach formers to the brake, there must be ½-inch clearance on the side of the formers against the bending leaf. The clamps are positioned vertically to the ground and tapped lightly with a mallet. This creates enough friction to hold the formers in place.

13-33. Some of the precautions to observe when operating a cornice brake include these:

- Short pieces of material should always be bent in the center of the brake to equalize the strain on the machine.
- SS angle bars should always be used with U5 and U6 bars to make narrow offset bends.

- Seams should never be bent unless you adjust links DD to clamp the full multiple thickness of the seam, and the top leaf should be set back for clearance of the same full multiple thickness.
- Rod, wire, band iron, or spring tempered sheets must not be bent on the cornice brake.
- The counterbalance is very heavy and can cause serious injury to you or other personnel if released improperly. The bending leaf should always be returned slowly to its proper position after completing a bend.

13-23. **Box and Pan Brake.** The construction of the box and pan brake is a great deal like that of the cornice brake except that the clamping leaf of the box and pan brake is divided into removable sections called fingers or shoes. These fingers, as shown in figure 59, vary in width and are interchangeable. This machine is especially designed for making boxes of various sizes and shapes, because it permits the forming of all sides without distorting any of the finished bends. If the need arises, this brake can be used to do most of the same type of work that can be done on the standard cornice brake. The main advantage a box and pan brake has over the cornice brake is that you may form pans or boxes with four sides by using different combinations or arrangements of the fingers.

13-24. Since the machine is a great deal like the cornice brake, all adjustments such as radius and thickness can be made the same as for the cornice brake. The steel fingers are secured to the upper beam by means of thumbscrews. The fingers must be securely seated and the thumbscrews tightened before the brake is used. To remove any of the fingers, the clamping bar is raised, the thumbscrews loosened, and the fingers pulled forward. When installing the fingers, the reverse procedure is followed.

13-25. Before starting any work on the box and pan brake, be sure all adjustments are made and are suitable for the gage of metal selected. Rod, wire, band iron, or spring tempered sheets must not be bent on the box and pan brake. Operation of the box and pan brake is similar to that of the cornice brake.

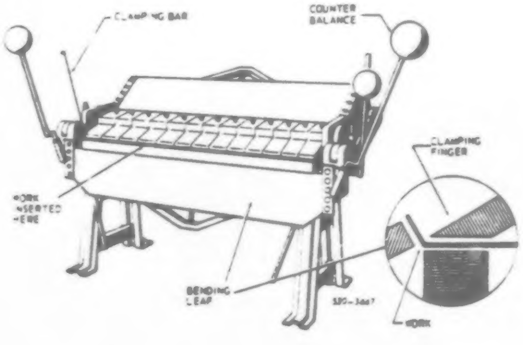


Figure 59. Box and pan brake.

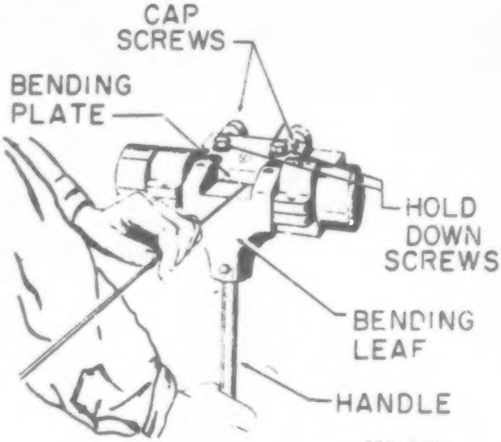


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Figure 60. Brace and wire bender.

13-26. **Brace and Wire Bender.** Rod, wire, and bar stock are used for braces, handles, and stiffeners in sheet metalwork. Since this round stock should not be formed on a folding machine, it must be bent in a brace and wire bender, in the grooves of a slip roll machine, or in a vise. With the brace and wire bender, such as that shown in figure 60, it is possible to make bends of various angles and radiuses. The bending plate is made to fit a variety of rod and wire sizes, and a heavy duty model will bend flat mild steel up to and including 1/8 inch thick and 3½ inches wide.

13-27. The radius of bend for rod, wire, and bar stock is determined by moving the bending plate forward or backward with the capscrews. The minimum distance of adjustment is the same as the size of rod, wire, or bar stock being formed. The holddown screws are used to adjust the bending plate up or down or to turn it around. When the bending plate is turned around it will accept flat material; however, for different thicknesses of flat material, it is also necessary to adjust the bending plate up or down. Maintenance of the brace and wire bender consists mainly of cleaning and lubrication. The bending leaf shaft has two oil holes which will require 2 or 3 drops of oil at intervals prescribed by your shop. As with other machines, the capacity of the brace and wire bender should not be exceeded.

13-28. To bend round material, the bending plate must be adjusted for the desired bend radius; then the rod or wire is inserted into a groove of appropriate size. The actual bending is done by pulling the bending leaf handle forward and up until the desired angle of bend is reached. To bend flat material, the bending plate must be reversed and adjusted to the thickness of the material as well as to the desired radius of bend. With the flat bar inserted, the actual bending is accomplished by pulling the bending leaf handle forward and up until the desired angle of bend is reached.

14. Forming Equipment

14-1. The most frequently used machines in the sheet metal shop include squaring shears, cornice brake, and slip roll forming machine. Other forming equipment include brace and wire bender, rotary machine, rotary burring machine, turning machine, wiring machine, elbow edging machine, setting down machine, crimping machine, beading machine, dollies, form blocks, and sandbags.

14-2. **Hand Operated Slip Roll Forming Machine.** The slip roll forming machine, illustrated in figure 61, is used to form sheets into cylinders of various diameters. The machine is simply constructed and consists of right- and left-end frames (housings) between which are mounted three solid steel rolls—two lower rolls and one upper roll. The two lower rolls are connected by gears operated by a handcrank. The lower front roll can be adjusted to the thickness of the metal by means of two knurled adjusting screws (one at each end of the roll). Once the metal is started into the machine, it is gripped between the lower front roll and the upper roll and is carried to the lower rear roll which bends it around the upper roll, thus forming a cylinder. If the adjusting screws at each end of the lower rear roll are turned to the right, a smaller radius will be produced; if the screws are turned to the left, a larger radius will be produced.

14-3. On most hand operated slip roll forming machines the upper roll can be released at one end which permits a formed cylinder to be removed from the machine without distortion. The rolls are grooved on the right end for forming wire and wired edges. The capacity of slip roll forming machines is determined by the manufacturer and must not be exceeded.

14-4. Slip roll operation is not a set procedure; however, the following is recommended: The lower front roll must be adjusted so that it and the upper roll will have a uniform grip on the metal. Once this adjustment has been made, the metal should ride smoothly through the rolls. In making a preliminary test it is best to select a piece of scrap material of the same gage as the metal you plan to form. The test piece is cranked through the gripping rolls until it comes in contact with the lower rear roll. Then by means of adjusting screws, the lower rear roll is set for the desired radius. This adjustment must be the same on both ends to form cylinders unless a taper is desired. A truncated cone or frustum is formed when the screws have different adjustments. When the rolling process is completed, the upper roll is released and raised. The test piece is then removed and final adjustments made. Place the material square with the rolls, and turn the crank clockwise. The cylinder that is formed should be the finished product. No change of adjust-

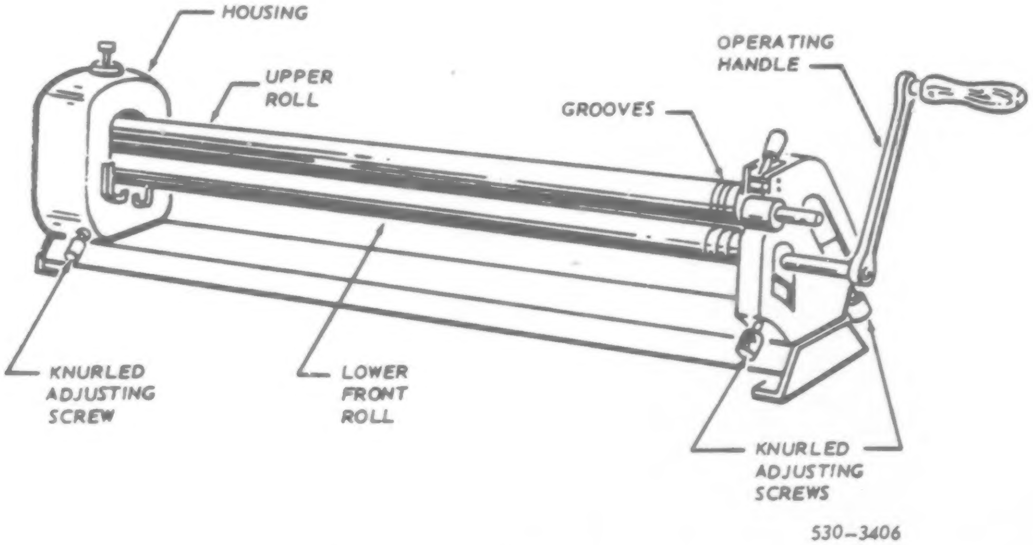

Figure 61. Hand operated slip roll forming machine.

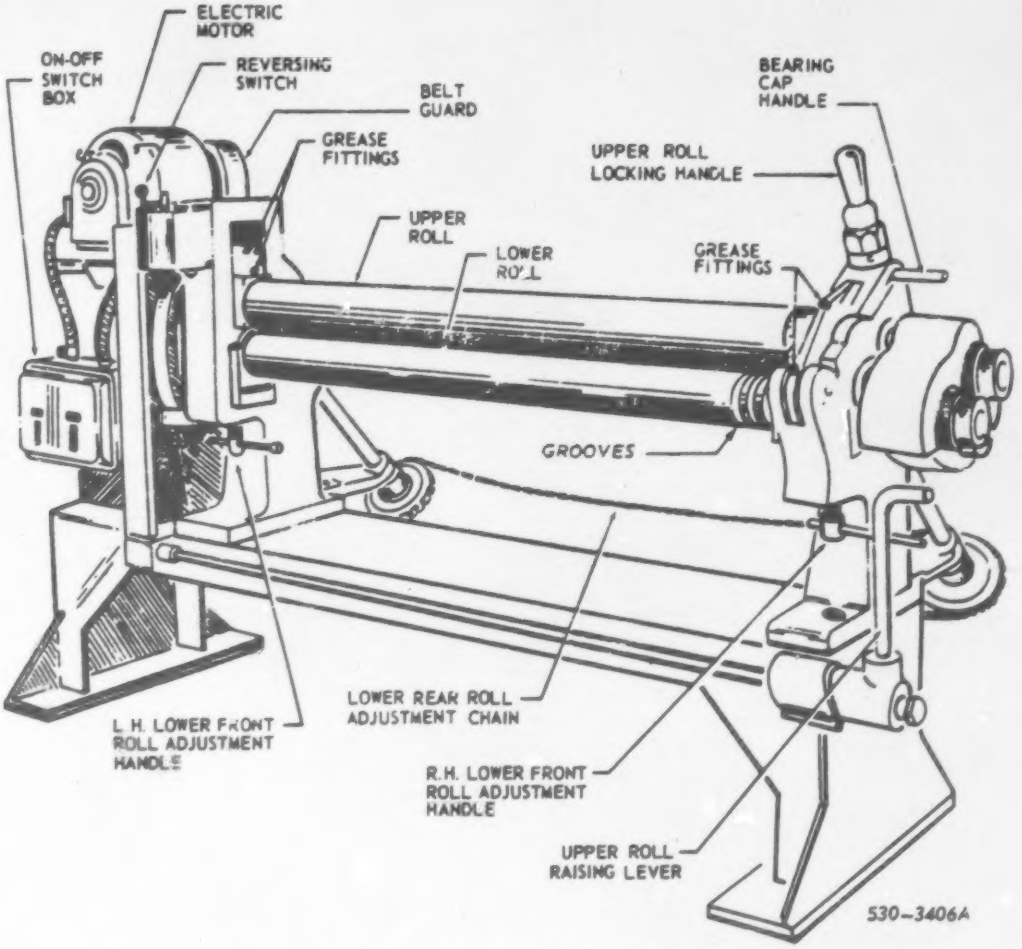
ELECTRIC MOTOR
ON-OFF SWITCH BOX
REVERSING SWITCH
BELT GUARD
GREASE FITTINGS
UPPER ROLL
LOWER ROLL
BEARING CAP HANDLE
UPPER ROLL LOCKING HANDLE
GREASE FITTINGS
GROOVES
LOWER REAR ROLL ADJUSTMENT CHAIN
L.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
R.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
UPPER ROLL RAISING LEVER
530-3406A

Figure 62. Power operated slip roll forming machine.

ments on the machine will be necessary if more than one item of the same size is to be formed.

14-5. **Power Operated Slip Roll Forming Machine.** The power operated slip roll forming machine, shown in figure 62, is a great deal like the hand operated slip roll machine in that it has two lower rolls and one upper roll. However, turning power for the rolls is supplied by an electric motor. Direction of the rolls is controlled with a reversing switch.

14-6. The power operated slip roll machine, like the hand operated version, has a limitation as to the diameter (radius) it can produce. When the machine is operating at maximum capacity (thickness and size of the sheet metal), the diameter of the cylinder formed should not be less than two times the diameter of the upper roll. If this recommendation is not followed, the formed cylinder will have flat spots at the seam.

14-7. The front gripping rolls can be adjusted for clearance (according to the thickness of metal to be formed) by turning screw handles located under the ends of the lower front roll. The lower rear roll can be adjusted for radius of bend by moving the endless chain. This chain turns adjustment screws at each end of the machine to keep the lower rear roll parallel with the gripping rolls. After the cylinder is formed, it can be removed by releasing the upper roll locking handle and pressing down on the raising lever located at the right-hand end of the machine.

14-8. Before starting the electric motor, you must press the ON button of the ON-OFF switch. Then move the reversing switch lever from the OFF position to the FORWARD position. This starts the motor and sets the rolls in motion for normal operation. When it is necessary to reverse the direction of the rolls, move the reverse switch lever to the OFF position until the rolls stop rotating, then move the lever to the REVERSE position. When a job has been completed, stop the rolls and remove power by moving the reverse switch lever to the OFF position and by pressing the OFF button of the ON-OFF switch.

14-9. Operation of the power slip roll machine is similar to that of the smaller, hand operated slip roll except that heavier gage metal can be formed. The heavier gage must be inserted and rolled for 7 to 9 inches, then backed out, turned around, and rolled from the other end in the regular way. This is done to prevent a flat spot along the seam.

14-10. Similar maintenance is performed on hand operated and power slip roll machines, such as lubricating the moving parts, keeping the rollers clean, and keeping the machines clear at all times. When the rollers get dirty, clean them with steel wool and a dry rag; then wipe them with an oiled rag to prevent corrosion.

14-11. You should observe safety precautions, such as keeping hand, fingers, and clothing clear of the rollers and drive gears, at all times. As with other machines, handle metal carefully to keep burrs from cutting your hands. Never apply power to the rolls until you are certain the machine is clear. If you are working on large jobs that require assistance from another workman, make certain that you both are qualified operators and that you understand which part of the operation each will perform.

14-12. **Rotary Machines.** The rotary machines illustrated in figures 63 through 69 are designed to rotate various shapes of matched roll dies which press sheet stock into desired shapes. Sheet metal is fed between these rolls in a similar manner to that for slip roll machines. Basically, a rotary machine consists of two shafts mounted in a frame. The rolls are mounted on one end of the shafts, and a pair of mesh gears and a handle (or pulley) are mounted on the other. The distance between the two rolls can be adjusted by a small crank located on top of the machine. Rotary machines are manufactured to operate either by power or by hand and, like many others, are equipped with gages to guide the metal. Such gages can be set to determine the depth at which a sheet passes between the rolls. Most rotary machines have a head position adjustment and lock screw, as shown in figure 63.

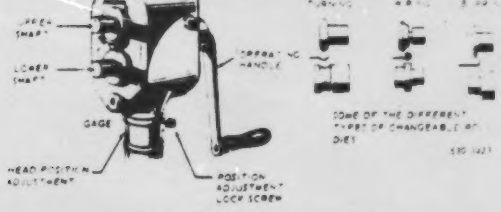

Figure 63. Rotary machine.

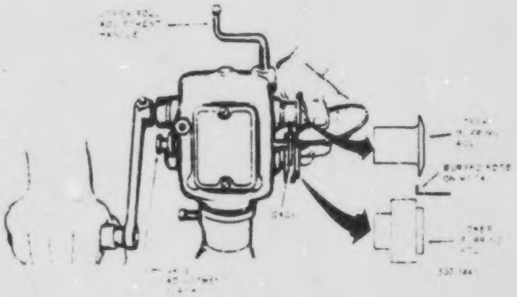

Figure 64. Rotary burring machine.

14-13. Because some rotary machines are designed for one specific operation, the operator must be certain of what each machine can do. This will be easy for you since the name of each rotary machine, in most cases, defines the job that it does. Typical examples are burring, turning, elbow edging, setting down, crimping, and beading machines.

14-14. The rotary machine illustrated in figure 63 is a combination of several rotary machines since by changing roll dies this machine can perform several operations. This machine has a combination rotary head that will accept turning rolls, burring rolls, and wiring rolls. To change these rolls, loosen the nuts on the end of the shafts and remove the rolls and replace them with rolls that are desired. Some of the nuts have left-hand threads; therefore, you should be careful when changing the rolls.

14-15. *Rotary burring machine.* A burring machine, such as that shown in figure 64, is used to turn flanges and edges on circular discs and cylinders. It is also used for turning edges on elbows and for making double seams and single hems when other machines are not available. An important thing to remember is that it will take considerable time, effort, patience, and practice to turn out a good job.

14-16. To operate the rotary burring machine, you must adjust and align it so that the side edge of the top roll protrudes over the shoulder of the bottom roll twice the thickness of the metal. The opening between the rolls should be equal to the thickness of the metal. Be sure these adjustments are correct because if the opening is too small, the top roll will act as a shear and cut the metal. The gage adjustment screw that controls the amount of metal turned up (flanged) is on the back side of the machine. Flange limits are from 1/8 to 1/4 inch.

14-17. To start the forming operation, place the disc in the machine and lower the top roll with the crank screw until the machine grips the metal and creases it slightly. Turn the crank slowly in a clockwise direction while keeping the edge of the disc firmly against the gage. Use caution to prevent injury to the hand when the disc is rotating between the thumb and forefinger. The first revolution of the rolls should be slow enough to permit the accurate starting of the burred edges. After the first revolution of the disc, it is possible to disregard the gage and follow the crease as the top pressure increases. Continue turning as before. Raise the disc slightly after each revolution until the full burred edge has been formed.

14-18. *Turning machine*. The turning machine, illustrated in figure 65, is used to form rounded flanges for wired edges. The rolls of this machine may also be used to turn double seams on elbows when an elbow edging machine is not available. The turning rolls are removable; thin turning rolls are available for light work and thick rolls for heavy work.

14-19. The first operation is to center the top and bottom rolls, then to adjust the gage so that it allows ample space for the wire. When the gage has been properly set, rest the cylinder to be wired on the lower roll, and press the edge against the gage. With the cylinder in place, lower the upper roll by turning the small crank screw, located on top of the machine, until a slight depression is formed in the metal. Turn the crank handle slowly until the cylinder has passed completely through the machine. Be sure to hold the metal firmly against the gage. After the first crease has been made, lower the upper roll, and pass the metal through the machine again with the work tilted upward. This process should be repeated several times to obtain the desired groove.

14-20. *Elbow edging machine*. The elbow edging machine, shown in figure 66, has elbow edging rolls that fit most standard makes of turning and burring machines. The upper roll of the elbow edging machine is V-grooved and has a matching lower roll. The rolls are made in three standard types to permit the fabrication of interlocking edges used in fastening various pieces of elbows together.

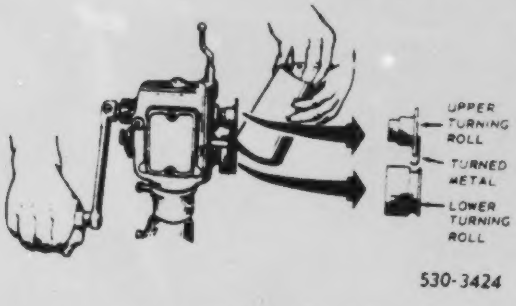

Figure 65. Turning machine

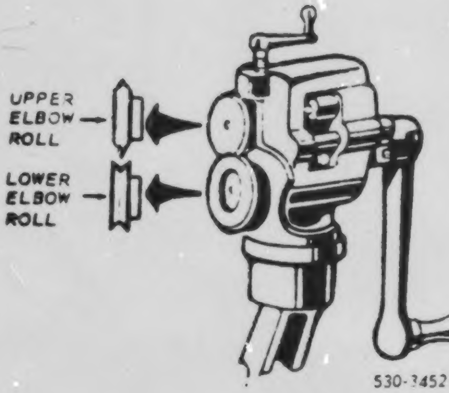

Figure 66. Elbow edging machine.

14-21. For making various types of edges, the operation is much the same. First, you must determine what lock seam is best suited for the job; then, screw the guide bar (gage) away from the rolls until the desired seam allowance has been made. If use of a guide bar is not practical, draw or scribe a line around the outside of the elbow section 1/8 inch from the edge to be joined. Make a similar line on the matching section inside the cylinder.

14-22. Place the first piece in the elbow edging machine so that the inside surface of the elbow will rest on the lower roll. Keep the edge of the elbow snug against the guide bar, and tighten the top roll until it forms a slight crease in the metal. Turn the handle slowly as you carefully guide the piece through. After one complete revolution of the elbow, tighten the top roll slightly, and repeat the process until a deep groove has been made around the edge of the elbow section.

14-23. The second piece is made in the same manner; however, the upper roll is placed on the inside of the cylinder.

14-24. Once the job has been completed, the lock should snap together with very little, if any, difficulty. If the flanges are too loose, they can be tightened with a hammer and stake.

14-25. *Setting down machine*. The setting down machine, shown in figure 67, is used for tightening or setting down the edges prior to double seaming. Two styles of setting down machines are available—one has the upper roll perpendicular to the lower roll, and the other has both rolls sloping toward the machine.

14-26. When double seaming the bottom of a

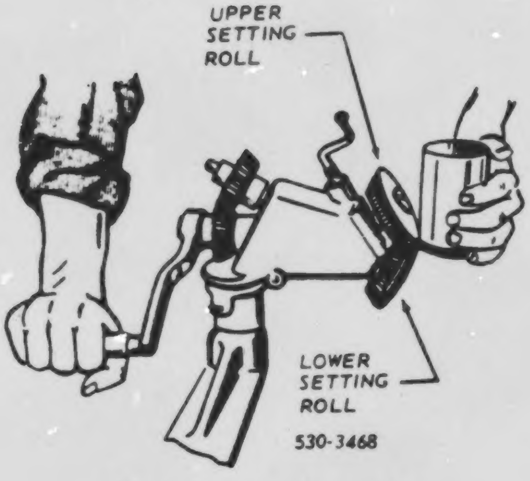

Figure 67. Setting down machine.

can or tank, hold the object in any convenient position, and run it between the rolls. The crank screw on top of the machine can be adjusted to any pressure necessary to close the seam.

14-27. Machine operation consists of placing the object between the upper and lower rolls and lowering the top roll. Medium pressure is desirable for the first revolution around the bottom of the object and should be continued until all wrinkles are removed. After this setting down operation has been completed, the seam must be turned up tight against the side with a mallet and stake or a double seaming machine.

14-28. *Crimping machine.* The crimping machine, shown in figure 68, is used to make one end of a pipe joint smaller than the other so that the two sections may be slipped together. Some of the crimping machines have combination beading rolls and crimping rolls. The bead serves to reinforce a formed cylinder and to prevent the crimped edge from slipping too far into the other cylinder.

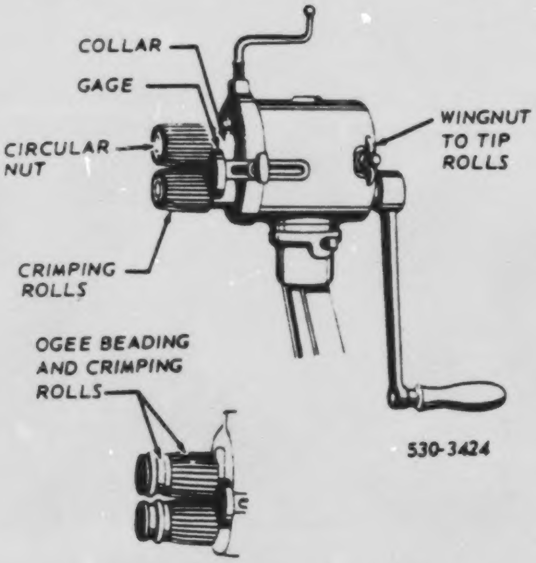

Figure 68. Crimping machine.

14-29. The mechanism is similar to that of most rotary machines. For jobs with riveted or grooved seams, the crimp is started near one side of the seam and run around the cylinder to the other side of the seam. Never crimp a seam, because its thickness will damage the rolls and spring the shafts of the machine.

14-30. When a pipe or object is to be crimped, it is inserted between the rolls, and the gage is adjusted to the correct width of the crimp desired. The top roll is lowered until it makes a slight depression in the cylinder as the operating handle is turned. This operation is repeated until the desired fit is obtained.

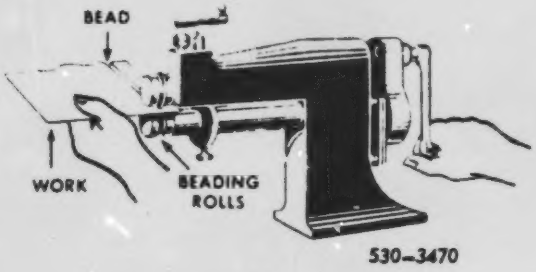

Figure 69. Beading machine.

14-31. *Beading machine.* The beading machine, shown in figure 69, is used for making beads in sheet metal objects such as cans, buckets, and pipes. Beads act as stiffeners and serve as stops for connecting two or more lengths of metal pipe. The beading machine is easy to operate, and with practice, high-quality work can be turned out. It comes equipped with several pairs of rolls which can be removed and replaced in the same manner as the burring and wiring machine rolls. The beading machine rolls that are generally used are single rolls, double rolls, triple rolls, and ogee rolls.

14-32. To operate the beading machine, place the cylinder between the rolls so that the top roll is on the outside of the cylinder. Place the edge of the cylinder against the adjustable guide (gage), and keep it there at all times or the beads will not meet after the first revolution. The adjustable guide can be set at different locations so that one or more beads can be made at different distances from the edge. Next, lower the rolls with the crank screw until a slight depression is made in the metal. Turn the handcrank with the

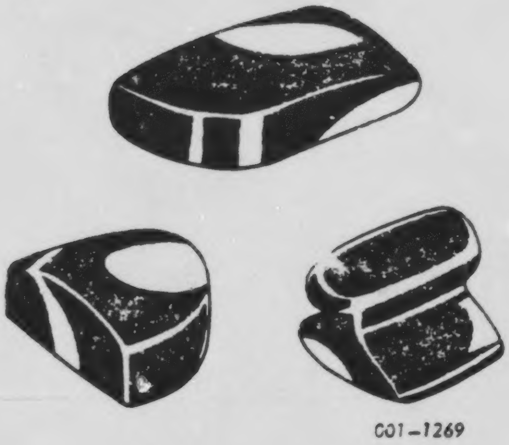

Figure 70. Hand dollies.

right hand as the work is guided with the left; and as the work revolves around the rolls, an impression is completed. Do not run the rolls over a seam, because that will damage the machine and weaken the seam.

14-33. **Hand Forming Equipment.** We have discussed several rotary machines which you may use to form sheet metal parts. However, there will be times when you will not be able to perform some jobs on a machine. In the following paragraphs we will discuss hand dollies, form blocks, sandbags, hammers, mallets, and vises. With these tools you will be able to do many jobs where a machine cannot be used or is not available.

14-34. Safety precautions should be observed at all times since most of the jobs you will be doing with handtools will be small and hard to hold. Be cautious of metal burrs, and keep hands clean when forming with these tools.

14-35. *Dollies.* Hand dollies which are commonly called bucking bars in sheet metal shops may be shop made or purchased commercially. They are available in various sizes and shapes, as shown in figure 70. They may be used when forming metal. They may also be used when riveting in places where access to the job is difficult or at jobs away from the shop where stakes are not available.

14-36. *Form blocks.* Form blocks are used as patterns or molds to form sheet metal into desired shapes. They can be made from hard wood or steel, although steel is best if you have many pieces of metal to form.

14-37. *Sandbags.* Sandbags are made of canvas dipped in wax to close the pores of the cloth. Fine dry sand is used as a filler which makes a firm backup cushion without hard lumps. Sandbags may be used for forming many shapes, because the sand filled bag is flexible. After forming or straightening metal using a raising hammer and a sandbag (or forming block), you may find it necessary to use a planishing hammer with dollies or stakes to finish the operation.

14-38. **Hammers and Mallets.** Hammers and mallets, illustrated in figure 71, are used often in the sheet metal shop for such jobs as riveting, raising metal, setting seams, and driving punches

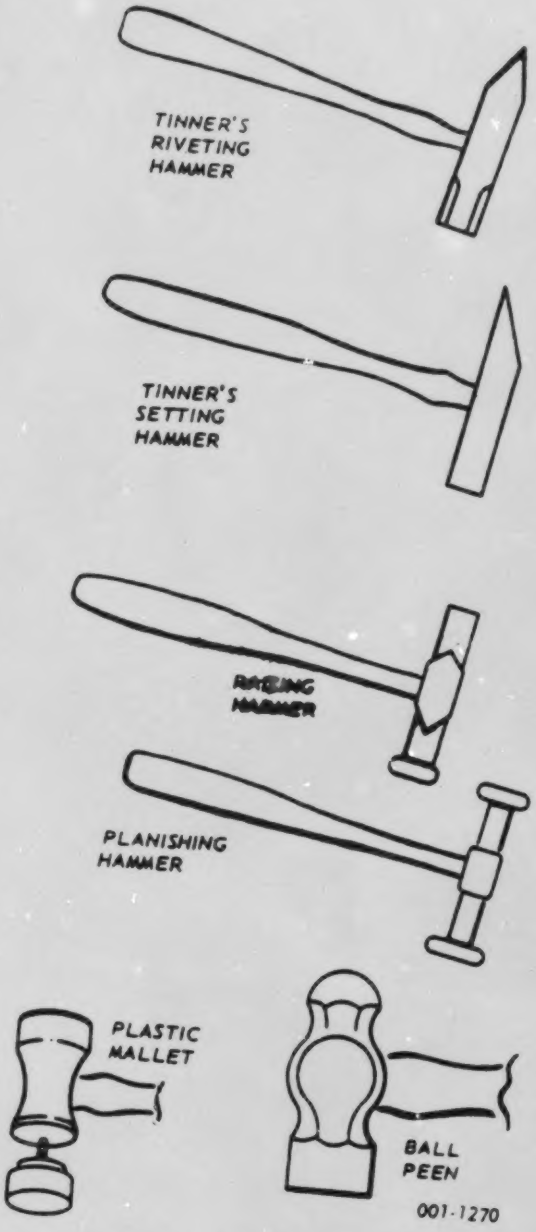

Figure 71. Hammers and soft-face mallets.

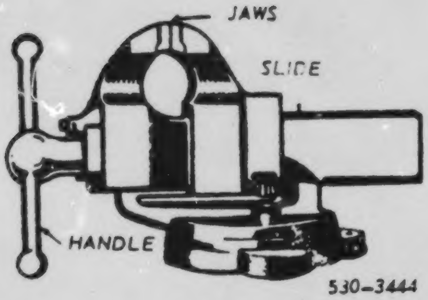

Figure 72. Bench vise.

and chisels. It is important to select the right hammer or mallet for the job.

14-39. The maintenance required to keep a hammer in good working condition consists of keeping the heads smooth and making sure the handle is good and properly secured to the head. As a safety precaution, make sure the wedge in the handle has not worked loose because if it has, the head could come off during use.

14-40. *Tinner's riveting hammer.* The tinner's riveting hammer has a square, slightly curved face with beveled edges to prevent the head of the hammer from marking the metal. The peen side is double tapered with a slightly rounded end; you will use this hammer often when riveting.

14-41. *Tinner's setting hammer.* The tinner's setting hammer has a square flat face for flattening seams without damaging the metal. The single tapered peen is used for setting down seams.

14-42. *Raising hammer.* The raising hammer is used to work soft, ductile metals by raising or stretching the metal over a forming block or sandbag to make such objects as metal bowls, shallow trays, and other similar items.

14-43. *Planishing hammer.* After an item has been partially finished on a forming block or sandbag, a planishing hammer is used to finish the part by removing any dents or wrinkles. A planishing hammer has flat rounded faces.

14-44. *Ball peen hammer.* The ball peen hammer has a variety of uses around a sheet metal shop. If you are working with punches, cold chisels, and other similar cutting tools, always use a ball peen hammer of the proper size. This hammer can be used also in riveting, peening, and raising metals.

14-45. *Claw hammer.* In many shops a common nail or claw hammer (not illustrated) is used to nail supports, to nail flat sheets of metal to wooden sheeting, to pull nails, and for other general utility purposes.

14-46. *Mallets.* Although they are not often mentioned as required tools, a wooden mallet, a plastic face mallet (or hammer), and, in some cases, a leather face mallet may be included in the sheet metalworker's toolkit or as a part of the sheet metal shop equipment. It must be remembered that hammer faces are made of harder metal than the material being worked and may damage soft metals such as copper, aluminum, and light gage sheet metal. When you are doing the preliminary shaping of these metals on stakes, use a wooden or plastic mallet whenever possible, finishing up with the proper metal hammer. Some examples of when you would use mallets are the forming of grooved seams and wired edges which require a great deal of handwork in fabrication.

14-47. **Vises.** A bench vise, such as that illustrated in figure 72, is a very important piece of equipment in the sheet metal shop. Bench vises are manufactured in many sizes and designs for different jobs. A vise with 4- or 5-inch jaws is commonly used in sheet metal shops to hold material for filing, forming, or sawing. The removable jaws are each secured with two screws and are usually grooved to prevent slipping of the material. When working with soft metal you should use jaws which are made of brass or aluminum and which are not so likely to mar the material being held. If jaws of soft metal are not available, use blocks of wood as a substitute.

14-48. Vises are usually secured to the workbench with screws or bolts; they have swivel bases to allow change of work positions for better access to the job. Avoid tightening the jaws too tight, because the jaws and the slide work on a worm gear; if tightened excessively, the worm gear will become worn and cause improper operation. The worm gear can be removed for

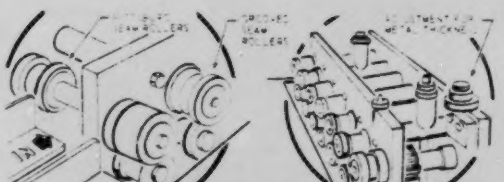

Figure 73. Pittsburg lock forming machine.

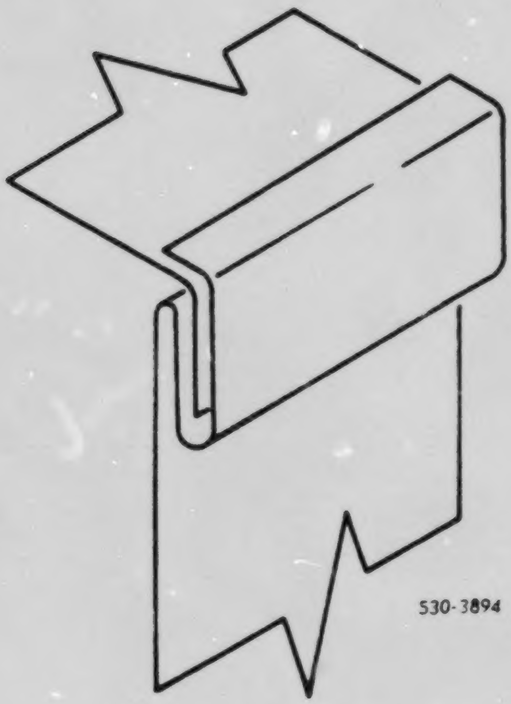

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Figure 74. Pittsburg seam.

cleaning, inspecting, and oiling by turning counterclockwise until it is disengaged from the vise.

15. Seaming and Locking Equipment

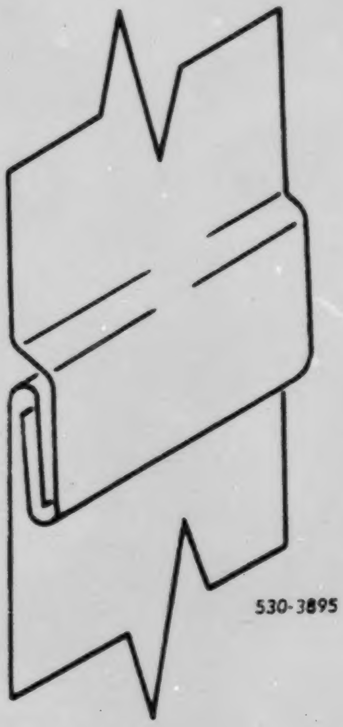
15-1. There are several machines and handtools that may be used to make seams and locks. We have already discussed bar folders and brakes. In this section we will discuss the Pittsburg lock forming machine, hand groovers, hand seamers, bench plates, and stakes for making seams and locks.

15-2. **Pittsburg Lock Forming Machine.** The Pittsburg lock forming machine, shown in figure 73, is used to form Pittsburg lock seams for corners of rectangular or square ducts and to form grooved seams for round ducts. These two seams are shown in the illustration. By changing the rollers, the Pittsburg machine may be used to form other shapes of seams. The machine illustrated can form 26- to 18-gage sheet metal by adjusting for metal thickness. Be careful to set the thickness gage correctly to prevent damage to the rollers, and never overload the machine. The machine has guides to keep the material straight as it is fed into the rollers and has a protective cover over the rollers. Although figure 73 shows this roller guard in the raised position in order to view the rollers the machine is never operated with the cover open. When the rollers are being cleaned or changed, electric power to the machine should be removed so the ON-OFF switch is inoperative.

15-3. Before using the Pittsburg lock forming machine, you should make seam allowances on the pattern, and you should notch the material. Usually, for a *Pittsburg seam* the allowance is 1¼ inches (1 inch for the seam side and ¼ inch for the flanged side). The 1-inch seam is formed by the machine as shown in the example of the Pittsburg seam in figure 73. The ¼-inch flanged edge is bent 90° on a brake machine then fitted into the groove of the 1-inch seam as shown in figure 74. Then the metal which extends above the groove is flattened to hold the seam tight.

15-4. Allowance for a *grooved seam,* such as that shown in figure 73, will usually require ½ inch on each side to make the seam plus an additional ½ inch because the seam will overlap. In figure 75 you can see how the grooved seam is secured by flattening the two parts.

15-5. Now back to using the Pittsburg lock forming machine. After setting the thickness gage to correspond with the material to be formed, turn the motor on and feed the material into the rollers. The material should be held flush against

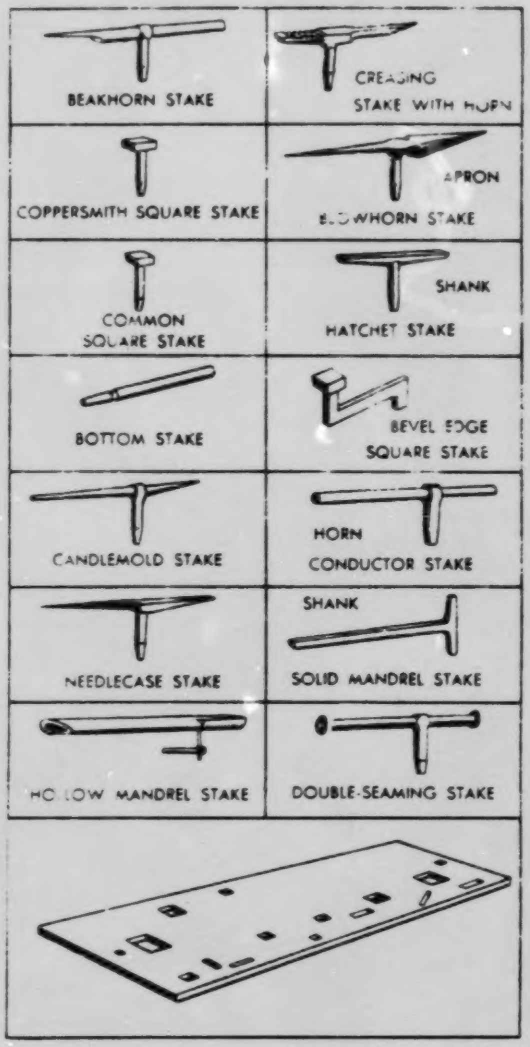


530-3895

Figure 75. Grooved seam.

the guide as it passes through the rollers, which are shown in figure 73. It is important to start the material straight because once it has started through the rollers, the machine will complete the operation whether it is straight or not. Keep hands and fingers away from the rollers during the forming operation.

15-6. The Pittsburgh lock forming machine, like other machines in the sheet metal shop should have a maintenance record folder, which will have a list of items to be inspected and serviced, intervals of inspection, and a place to record and initial the maintenance completed. The manufacturer's handbook or the technical manual will specify exactly what parts are to be serviced including lubrication of the rollers and drive gears. If the motor does not have sealed bearings it will require lubrication also. The rollers should be kept clean and should be wiped with an oiled rag to prevent corrosion.


BEAKHORN STAKE
CREASING STAKE WITH HORN
COPPERSMITH SQUARE STAKE
APRON
BLOWHORN STAKE
COMMON SQUARE STAKE
SHANK
HATCHET STAKE
BOTTOM STAKE
BEVEL EDGE SQUARE STAKE
CANDLEMOLD STAKE
HORN
CONDUCTOR STAKE
SHANK
NEEDLECASE STAKE
SOLID MANDREL STAKE
HOLLOW MANDREL STAKE
DOUBLE-SEAMING STAKE

530-3483

Figure 76. Bench plate and stakes.

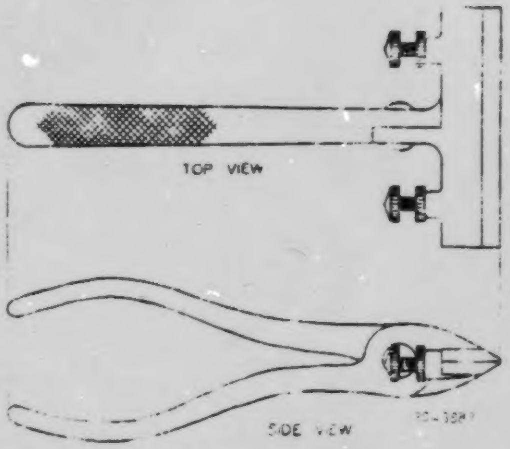

TOP VIEW
SIDE VIEW

Figure 77. Hand seamer.

15-7. **Hand Seaming Equipment**. The hand seaming equipment discussed in this section includes bench plates, stakes, hand seamers, and hand groovers.

15-8. *Bench plate and stakes.* Much of the work done in the sheet metal shop requires some handwork, such as shaping, seaming, and riveting. To do this work, small anvils, referred to as stakes, have been designed to perform many types of shaping and seaming which cannot be done by machines. These stakes, which consist of a horn, head, and shank, are fastened either in a vise or to a bench plate. Figure 76 shows a bench plate with a set of stakes designed to do almost any sheet metal forming that can be done by hand. The stakes described in the following paragraphs are the ones most often used. Other stakes include the beakhorn, common square, hatchet, conductor, coppersmith square, bottom, bevel edge square, and solid mandrel stakes.

15-9. The *candlemold stake* has two horns of different tapers and is used in forming, riveting, or seaming long, flaring articles.

15-10. The *hollow mandrel stake* has a slot running through its length in which a bolt slides, permitting the stake to be fastened to the bench at any angle or length. The rounded end is used for riveting and seaming pipes. The rectangularly shaped end is used for forming laps, riveting, and double seaming corners of pans, boxes, and similar sheet metal items.

15-11. The *creasing stake* has a round, tapered horn at one end and a rectangularly shaped horn with grooves on the other. It is used for forming, riveting, or seaming small, tapered articles; for creasing metal; and for bending wire.

15-12. The *needlecase stake* is used to do very fine handwork. It has a small, tapered horn at one end and a round beveled edge at the other.

15-13. The *blowhorn stake* has a short, tapered horn (apron) at one end and a long, tapered horn at the other. It is used in forming, riveting, or seaming tapered articles such as funnels and pitched covers.

15-14. The *double-seaming stake* is constructed with ball-shaped ends and is used for double seaming.

15-15. *Hand seamers.* Hand seamers are used to fold light gage metal and to form seams or joints. Figure 77 illustrates two views of a hand seamer you may use which has screws on either side of the head. These are adjustable for different width seams. Jamnuts prevent the screws from slipping, which might cause an uneven bend while folding the seams. This is also true for bends longer than the width of the hand seamer. The hand seamer is useful when turning edges for seams on small jobs and when the brake or bar folder is not available.

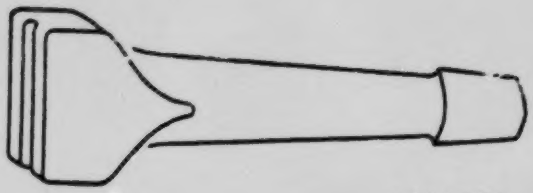


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Figure 78. Hand groover.

15-16. *Hand groovers.* The hand groover illustrated in figure 78 is used to groove seams after they have been formed. It is useful for small jobs or when a Pittsburg machine is not available. Hand groovers are available in several sizes and will be issued with your toolkit. The hand groover may be used to form a grooved seam such as that illustrated in figure 75. The two edges may be turned back 160° with a folding machine or with a hand seamer. The two turned back edges are hooked together and placed over a backing surface; then the hand groover is placed over the lapped edges and struck with a hammer to set down the edges of the seam as shown in figure 75.

CHAPTER 5

Soldering, Spot Welding, and Sealants

AS THE NAME of this chapter implies, the following discussions will concern soldering, spot welding, and the use of sealants. You will study the equipment and materials used for soldering sheet metal as well as the techniques and safety procedures involved. Later in the chapter we will discuss spot welding equipment, including its application, use, and maintenance. The final section of the chapter is a discussion of sealants used in sheet metalwork, such as sealing tape, contact cement, and calking compound.

2. Like other steps of the fabrication process (layout, cutting, and forming), soldering, spot welding, and sealing are also important. The quality of the finished component depends on how well you perform each step. Also like the equipment used in the fabrication process, it is important to properly maintain the equipment and to follow all safety precautions.

3. The knowledge you gain from this chapter will not only help you answer questions but will actually be used when you are assigned to solder, spot weld, or seal sheet metal components. You will frequently solder such articles as pans, tanks, gutters, and gravel guards. You will spot weld such articles as pans, filter frames, louvers, and other articles where excessive vibration is not encountered. You will use sealants for sealing joints and seams. Observance of all safety precautions when using gasoline and flammable cements may prevent severe burns, save your life, and prevent damage to equipment and buildings.

16. Soldering

16-1. Soldering is the process of joining two pieces of metal by the use of a third metal or alloy which has a lower melting point than either of the metals to be joined. The solder is flowed (melted) between the surfaces and left to cool. As the solder cools, it hardens and cements the two pieces of metal together. Although the joint produced by soldering is weaker than a joint produced by other methods, soldering is especially useful for making airtight and liquidtight joints that do not have to withstand much pull or vibration. Iron, tin, galvanized iron, copper, stainless steel, and brass are metals which are commonly soldered.

16-2. Equipment for soldering includes soldering coppers, tinner's furnaces, fire pots, blowtorches, solder, fluxes, acid brushes, and tinning compounds. We will discuss the use and care of each of these.

16-3. **Soldering Coppers.** There are three shapes of fire heated coppers used in most sheet metal shops. Figure 79 illustrates the regular square point copper, bottom copper, and roofing copper.

16-4. The *regular square point copper* is used a great deal since the point may be forged and shaped for different type soldering tasks.

16-5. *Bottom coppers* are used to solder pan bottoms, large tanks, and other flat bottom objects.

16-6. *Roofing coppers* are used to solder all types of metal roofing, flashing, and gravel guard.

16-7. Fire heated soldering coppers are sized by weight per pair. For example, the 6-pound copper used for soldering seams consists of two coppers weighing 3 pounds each. The weight of a copper includes head weight only; the shank and wooden handle are not included. It is important to select the proper size and shape of

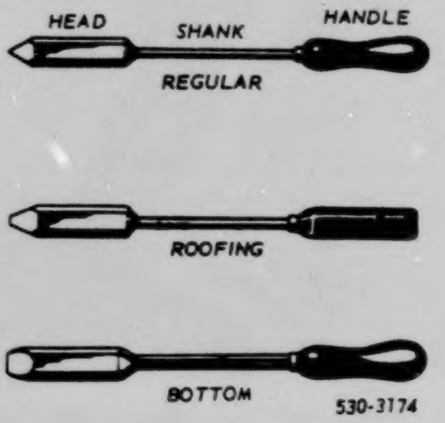

Figure 79. Soldering coppers.

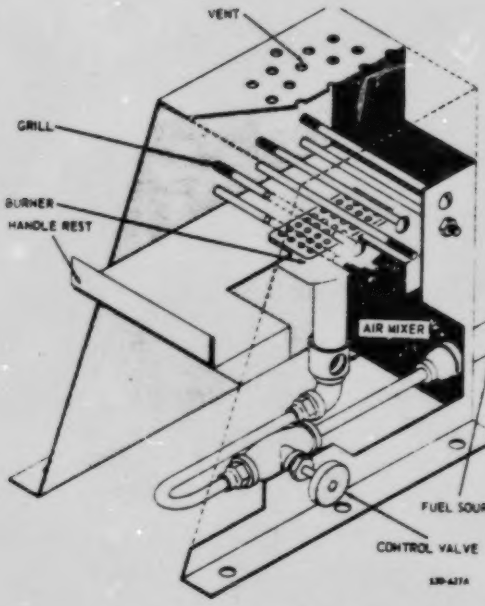

Figure 80. Tinner's furnace.

coppers. Normally, when soldering with a pair of coppers you will be heating one while using the other. This speeds the operation by allowing the surface to remain hot.

16-8. Electrically heated soldering coppers (irons) are sized by the wattage of the heating element and may be used for some soldering tasks. Two sizes of electric soldering irons which you may have in the sheet metal shop are 200 watts and 550 watts. The 200-watt size can be used for light jobs such as soldering screen wire to light gage metal frames, and the larger 550-watt size can be used for jobs such as soldering seams on metal up to 18 gage.

16-9. To perform satisfactorily, all types of fire heated and electrically heated soldering coppers must have a well-formed, well-cleaned, and well-tinned point. The handles of fire heated soldering coppers should be checked often to see that they are securely attached to the shank. Broken handles should be replaced.

16-10. **Tinner's Furnace.** A tinner's furnace, such as that illustrated in figure 80, is used to heat soldering coppers for jobs being soldered in the shop. The furnace is mounted on a bench and may be a single or double burner model. It uses natural or artificial gas for fuel and is equipped with an adjustable control valve. Some furnaces have a pilot burner to ignite the main burner quicker and easier. The single burner tinner's furnace is recommended for coppers up to 6-pound size, and the double burner furnace is recommended for heavier coppers. Be sure to read and observe all safety rules when operating a tinner's furnace, since it can be hazardous if improperly used. In figure 80 you can see the principal parts of a typical tinner's furnace.

16-11. **Fire Pot.** Fire pots, such as that shown in figure 81, are available in many sizes and types and are used to heat soldering coppers in the shop or in the field. The fire pot is equipped with a wind deflector and can be used to heat two coppers at a time. Unleaded (white) gasoline is used for fuel. Air pressure is used to force the fuel into the generating coil or chamber, which is kept hot enough to vaporize the fuel. Although operating procedures are similar to the operating procedures for a blowtorch, you should carefully follow the instructions for the particular fire pot you are using. The fire pot requires very little maintenance as long as you use only unleaded gasoline. In figure 81 you can see the principal parts of a typical fire pot.

16-12. **Blowtorch.** The gasoline blowtorch, shown in figure 82, may also be used for heating soldering coppers in the shop or in the field; however, the blowtorch is smaller than a fire pot and not as efficient. Since the blowtorch is easier to carry, it is used mainly for small jobs or where portability is a factor. In figure 82 you can see the principal parts of a typical blowtorch. For heating, the head of a soldering copper is placed in the flame and the shank on the two rest points.

16-13. To operate the blowtorch, fill it about two-thirds full of clean, unleaded gasoline, and pump sufficient air pressure into the tank to cause the gasoline to flow when the valve is opened. However, don't pump too much because excessive pressure may rupture the washers and seals.

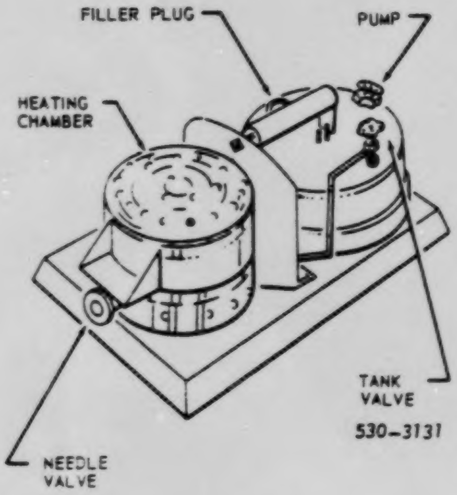

Figure 81. Fire pot.

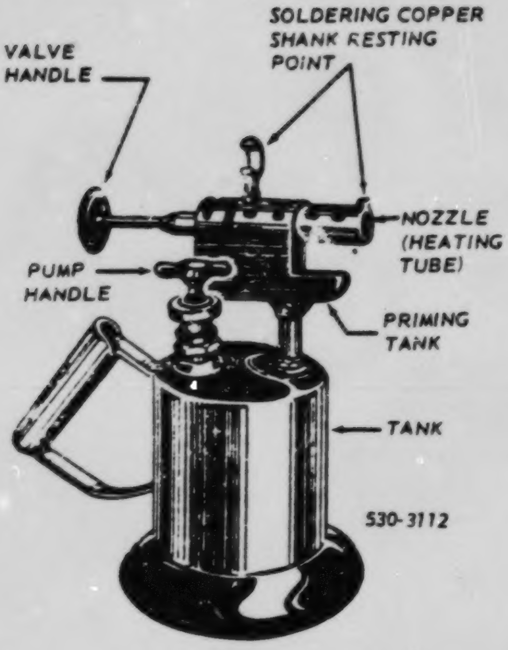

Figure 82. Blowtorch.

When the valve is opened, liquid gasoline flows from the jet of the torch and drips into the priming tank (pan). Close the valve when the pan is about three-fourths full; then ignite the gasoline with a match. The flame from the burning gasoline in the priming pan heats the perforated nozzle (heating tube). When the nozzle is sufficiently hot, open the valve slowly, allowing the gasoline vapor that has been formed to flow from the nozzle where it will ignite and burn with considerable force. Adjust the flame to the desired intensity by turning the valve counterclockwise. For best results, adjust the valve so that a clean, pale blue flame is produced. If the pressure in the torch decreases, it is permissible to pump in more air while the torch is in operation. When you are through using the torch, close the valve, and tighten it sufficiently to prevent gas from escaping. Remember that the hot metal will contract when it cools and will cause the valve to stick.

16-14. The gasoline blowtorch requires very little maintenance as long as you use only unleaded gasoline. If leaded gasoline is used, a compound will form that will stop up the gasoline passage, and the torch will be a source of trouble from that time on, since it is almost impossible to clean the passages thoroughly. Insufficient heating from the priming pan is the cause of most difficulties in lighting a blowtorch.

16-15. **Solder.** A mixture of tin and lead called solder is used extensively in the sheet metal shop to seal seams and joints. Three commonly used blends of solder are 40/60, 50/50, and 60/40. In the first example (40/60) the 40 represents the percent of tin, and the 60 represents the percent of lead. When pure tin (which melts at 450° F. (Fahrenheit)) and lead (which melts at 620° F.) are mixed, they become a fusible alloy which melts according to the mixture. You will find a good all-around solder to be the 40/60 mixture, which melts at 464° F. The 50/50 mixture melts at 428° F., and the 60/40 mixture at 374° F. These blends of solder are available in wire form and in bars weighing from ½ to 1½ pounds.

16-16. **Flux.** Before soldering, the surface of the metal must be treated with a flux to remove oxide, to prevent oxidation during heating, and to lower the surface tension of the solder so that it will flow properly. Corrosive fluxes which you will be using include zinc chloride and muriatic acid. Following the use of a corrosive flux, the surface of the metal should be rinsed with water to prevent the flux from acting on the metal that has been soldered. Corrosive fluxes are usually applied with a brush commonly called an acid brush. This brush is dipped into the liquid flux then used to spread it on the metal which is to be soldered. Each time after use, the acid brush should be rinsed in running water to prevent the corrosive action of the flux from ruining the bristles. Most fluxes are harmful to your skin and clothing, and you should be careful to keep flux off. Running water should be used immediately to rinse off any flux which may get on your skin or clothing. Tools should also be protected from corrosive fluxes, and liquid fluxes should be stored with the containers closed.

16-17. Rosin is a noncorrosive flux which is used when soldering bright copper, such as roofing and electrical wiring. Rosin prevents oxidation during heating, although it does not remove oxidation as do the corrosive fluxes. Rosin is available as a powder or a paste; either may be melted on the surface with a hot iron.

16-18. **Tinning Compound.** Tinning compounds are used with solder to coat and clean soldering coppers after shaping and filing. Sal ammoniac is a good tinning compound which you will normally use; however, rosin may also be used to tin coppers.

16-19. **Shaping and Tinning Soldering Coppers.** Now that you have read about soldering coppers, solder, and fluxes, this is a good time to learn how a copper may be shaped and tinned. After heating the head of the copper to a cherry red, shape the tip of the head on an anvil or solid plate, using blows from a heavy ball peen hammer. After the copper has been worked into the desired shape, reheat it to a cherry red, and file it with a single-cut bastard file until it is smooth and clean. When ready for tinning, the copper is reheated just enough to melt the solder. The heated copper and just enough solder to coat the tip is placed on a sal ammoniac bar then rubbed back and forth until the entire surface of the tip becomes tinned with a light coating of solder. A hot soldering copper will crack the sal ammoniac bar if held in one place too long.

16-20. During the soldering process it is necessary to keep the tip of the copper clean by dipping it into a sal ammoniac solution. This solution is mixed by using ½ ounce of powdered sal ammoniac to 1 quart of clean water. If a dipping solution is not available, you may use a cotton rag. Wipe the heated tip lightly and quickly across a cotton rag. (Do not use rags made of materials other than cotton.) Remember that tinning the coppers and keeping them clean is important in order to perform good soldering jobs.

16-21. **Soldering Techniques.** As a sheet metalworker you will be soldering galvanized iron, stainless steel, copper, lead, brass, and bronze. However, most of your soldering will involve galvanized iron where the solder is used as a sealer for joints and seams to make them liquid-tight. To make a properly sealed seam or joint, it is necessary to sweat the solder. Sweating is the process of flowing solder into heated joints or seams. In cases such as sweating small lap joints, the metal being joined is tinned (covered with a thin coat of solder) before joining. After tinning, the metal is placed together and heated with a copper which causes the two tinned surfaces to form a good joint.

16-22. *Soldering rivited seams.* When you solder a riveted seam, the rivets as well as the seam must be soldered to insure a well-sealed seam. After applying flux with an acid brush, move the heated copper slowly along the seam, sweating the joint and adding solder to the seam and rivets as needed. Remember to apply the solder to the surface, not the copper. If the surface is heated properly, the solder will flow evenly onto the seam and around the rivet heads.

16-23. *Soldering grooved seams.* The method for soldering grooved seams is similar to soldering riveted seams, except there are no rivets to be soldered. One example is the soldering of grooved seams when installing metal roofs.

16-24. *Resoldering.* In some cases you will be required to resolder joints or seams that are dirty from use, such as drip pan seams that have grease or oil in the pores of the old solder and metal. In this case you need to melt and remove the old solder by wiping with a clean damp cotton rag. After this wiping, apply the flux, heat the surface again, and apply enough solder so that it can be wiped several times with a clean damp cotton rag. This procedure removes any remaining grease from the pores and at the same time tins the surface. After this cleaning and tinning have been done you may solder the metal like you would a new seam or joint.

16-25. *Cooling and cleaning a soldered surface.* After soldering has been completed, allow the surface to cool slowly until the solder is solid. When heated and cooled properly, the solder will have a bright shiny appearance. If corrosive flux is used, you can use warm clear water to clean it from most metals. However, to clean stainless steel, use warm soapy water mixed with washing soda to prevent streaking. After cleaning the excess flux, rinse the surface; then dry it with a clean rag to help prevent streaking and staining.

16-26. *Safety precautions.* Safety precautions when you are using soldering equipment are very important. For example, soldering equipment such as the blowtorch and fire pot *should not* be used in unventilated areas. This equipment should be checked for safe operation in accordance with the manufacturer's handbook or the technical manual.

16-27. When a blowtorch or fire pot is filled with unleaded gasoline, it is best to do it out of doors. If filling must be done indoors, you should make certain there are no sources of ignition, such as a pilot burner, open flame, or sparking equipment. Gasoline for the fire pot or blowtorch must be kept in outside storage areas for safety purposes, and the storage tank should be marked to designate unleaded gas. Do not smoke when filling the tank or going to the storage area.

16-28. The fire pot or blowtorch should be placed on a firm foundation away from walls or other combustible materials and should not be ignited if gasoline has been spilled. Blowtorches or fire pots should not be moved until all of the gasoline in the priming tank has burned away.

16-29. Soldering coppers should be treated as if they were hot at all times, since a hot copper can cause a serious burn. They should also be checked before use to see that the shank is held firmly in the handle. The dry, cotton cleaning rag should *not* be held in the hand when wiping a copper but should be placed so that the heated copper can be pulled over the rag.

16-30. You should avoid breathing the fumes from the flux or acid since the fumes are harmful when inhaled. You should also avoid using too much solder as it may drip and burn you or other personnel.

16-31. Electric soldering irons should not remain connected to the electricity when not in use. The cords and connections should be checked often for breaks in the wire, insulation, and prongs.

17. Spot Welding

17-1. Spot welding, or resistance welding as it is sometimes called, is a pressure welding process in which heat is generated by resistance to the flow of electrical current. No flux or welding rod is required during the weld time because the surfaces of the sheets become fused while they are pressed together and electrical current is applied. However, the surfaces must be cleaned prior to welding. It is important to remove paint, grease, oxide, or any foreign matter that may interfere with the resistance of the surfaces being joined.

17-2. **Spot Welder.** The spot welder illustrated in figure 83 is the type found in many sheet metal shops. The upper arm is actuated by air pressure and is lowered and raised in a vertical arc. The spot welder illustrated uses 90 psi of air pressure and is used primarily to weld light gage metal. This spot welder must have a source of electricity, air pressure, and water.

17-3. *Settings.* Three factors must be controlled when you are resistance welding—current, time, and pressure. If you overlook any of these, a poor weld will result.

17-4. The amount of *current* (amperage) applied to the work is selected with a control knob which controls the heat used for making the weld. This control knob is turned clockwise to raise the amperage, and each step around the dial adds 10,000 amperes. Most spot welders have a maximum output of 80,000 to 100,000 amperes.

17-5. There are two periods of *time* to be controlled during the operation of a spot welder—weld time and hold time. Weld time is the time the current actually flows through the electrodes and weld area. Hold time is the time allowed for a weld to cool before the electrode force is removed. These time periods are each selected with a control knob and dial.

17-6. *Pressure* is controlled in resistance welding by air pressure applied to a cylinder that is connected to the upper arm of the spot welder. This force on the upper arm and the electrodes press the two sheets together at the point to be welded. Air pressure is selected by turning a slotted adjustment screw while observing the pressure gage.

17-7. *Electrodes.* Electrodes are usually alloy cylindrical rods with various shaped tips. The electrical conductivity of the electrodes must be great enough to allow sufficient heating at the point of the weld without excessive heating at the tips of the electrodes.

17-8. The life of the electrodes is increased by water which is circulated inside each electrode to prevent overheating. It is important to turn the water on before using the spot welder and also important to turn the water off after use. If the water is left on, it may cause harmful condensation on the transformer cooling pads.

17-9. The radius of the electrode tips deter-

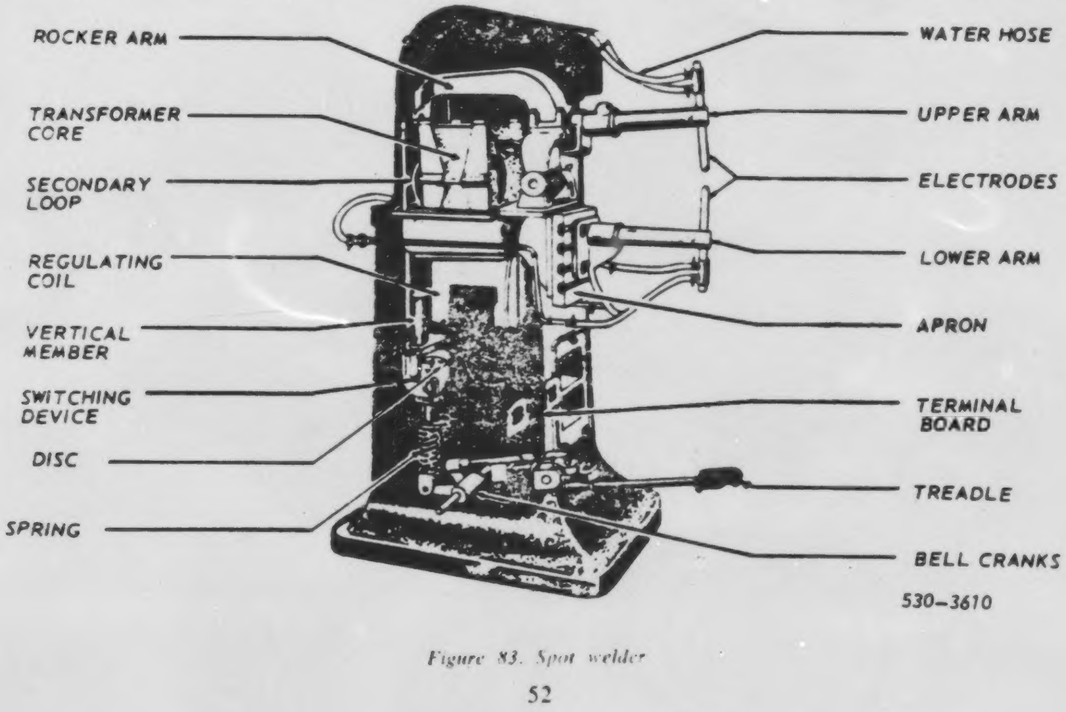

Figure 83. Spot welder

mines the size of the spot weld. If the tips are too small, the weld may lack strength. If the tips are too large, the weld will have a poor surface appearance because the required additional heat will cause localized overheating.

17-10. **Application, Use, and Maintenance of Spot Welders.** Nearly all metals may be spot welded. Some have different characteristics and will require different settings of the machine. When welding any metal, its surface must be free of oil or any foreign material. You should check the manufacturer's handbook or the technical manual for these settings.

17-11. *Weldability of dissimilar materials.* Dissimilar materials are difficult to join and present problems not met in welding similar metals. For example, suppose you are welding stainless steel to a nickel alloy of steel. You will have to use a different electrode for each metal because the welding resistances are different. The metal with the greater resistance will become hotter than the one with less resistance, and the desired fusion of one metal into the other will not occur properly. The selection of electrodes for a spot welder is just as much of a problem as finding the proper cement for bonding resins. Electrodes are chosen for their freedom from sticking to the metal that is being bonded.

17-12. *Spot welding aluminum.* Because of the inherent characteristics of aluminum alloys, it is necessary to use procedures that differ somewhat from conventional spot welding. The electrical conductivity of aluminum is much higher than most metals, and this factor requires higher welding currents.

17-13. Aluminum does not have a plastic range—a characteristic permitting a weld to be made without converting it to the liquid state. When welding aluminum, precise control is required of the energy input into the weld so that the material at the inner contact point will be brought to the melting point but surfaces in contact with the electrodes will remain relatively cool.

17-14. The oxide which forms on aluminum sheets must be removed before the welding process is started, since the oxide has a high and erratic electrical resistance. This resistance affects the amount of heat produced at the weld. Hydrofluoric acid in paste form is normally used to clean aluminum before spot welding, but after a few seconds it is washed off under running water.

17-15. The electrode tips must be cleaned and reshaped frequently when welding aluminum because aluminum has a tendency to alloy with the copper tips.

17-16. *Application and use.* You will use the spot welder many times in the sheet metal shop. For instance, it may be used when making a lap seam, fastening corner seams, when making drip pans or similar jobs, or when making metal louvers that will be installed between studding. The outside of a spot welded louver will be smooth and a close fit can be obtained.

17-17. When spot welding, always wear protective equipment prescribed by safety directives at your base. This includes protective clothing, goggles or safety glasses, and a face shield. The sparks are hazardous to eyes and skin and may travel a distance of several feet.

17-18. *Maintenance.* Proper maintenance of spot welders is very important if good welding is to be done. Electrodes must be dressed (cleaned) because they become pitted through continued use. Dressing is done with the electrodes in correct alignment and with a mill file used on the points until the desired diameter is obtained. Emery cloth is used to finish the points to a slight dome. Another maintenance item is cleaning the water lines inside the electrodes; these should be cleaned and flushed every week to 10 days.

18. Sealants Used in Sheet Metalwork

18-1. In this section we will discuss sealants such as sealing tapes, asphalt roof cement, contact cement, and calking compounds. Sealants are used to make airtight or watertight joints and seams; they should not be depended on for holding strength. For instance if you are setting a roof jack, it should be nailed to the roof and then sealed around the edges. Other uses of sealants include the sealing of doors and window facings of metal buildings and the sealing of joints and seams of ducts. You should follow the manufacturer's instructions when using sealants.

18-2. **Sealing Tape.** One type of sealing tape is the impregnated zinc chromate tape, which is used to seal joints and seams. If you are making a lap seam, you can apply tape between the two surfaces before fastening them.

18-3. **Cement.** Contact cement may be used to seal joints or seams, for securing fiberglass duct lining, and for securing metal tops to wood tables and counters. After selecting a suitable cement that will adhere, coat both surfaces and allow them to become tacky before joining them. You must join the two surfaces carefully because the cement is so sticky it may be difficult to separate if realignment is necessary. Most contact cements should not be used near open flames or in a closed area.

18-4. Another type of cement you will be using is asphalt impregnated roofing cement. It adheres to woods, metal, and asphalt roofs. It is used to seal roof jacks, ventilators, flashing, and similar parts on roofs.

18-5. **Calking Compound.** Calking compound is useful for sealing metal joints on buildings. It is commonly available in tubes to be used with a dispenser called a calking gun. However, it is also available in quart and gallon cans as well as in rolls approximately 1 inch wide and ⅛ inch thick. The roll form is useful when installing window and door edging or similar jobs. The calking is applied, and the part is lapped over or under.

18-6. When using a calking gun to seal joints or seams, hold the gun at a slight angle in order to see the calking as it is applied. When you have finished using a calking gun, release the trigger mechanism so that the calk will not continue to flow from the tube.

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This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, "Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

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STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

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200	Fastening Sheet Metal with Rivets, pages 1-4
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202	Maintenance of Tools and Equipment; Hand Snips and Shears, pages 11-13
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CHAPTER REVIEW EXERCISES

The following exercises are study aids. Writer your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

Note for Mandatory CDC Students:

The Job Training Standard knowledge elements specified for the 3-level trainee are contained in Volume X or CDC 10000 and in those text subject areas that contain the answers for the review exercises preceded by an asterisk (*).

CHAPTER 1

Objectives: To exhibit a knowledge of fastening hardware and devices used to assemble, align, and fasten sheet metal components in permanent and semipermanent installations.

*1. What is the size of the tinner's rivets in a half-filled box that weighs ½ lb. and contains 500 rivets? (1-3)

*2. What size of tinner's rivets should be used to join two sheets of 24-gage sheet metal? (1-3)

3. What size tinner's rivets should you use to rivet a hanger to a duct such as shown in view B (right) of figure 18? The hanger and duct are both made of 16-gage metal. (1-3 and Fig. 18)

*4. How far from the edge of the sheet should a rivet hole be drilled or punched for a rivet with a ¼-inch diameter head? (1-7)

5. In figure 53, the Whitney punch is being used to make rivet holes. If rivets with heads ⅜-inch diameter are to be used, what is the minimum distance the centerline can be from the edge of the sheet? (1-7 and Fig. 53)

*6. Fill in the blanks. According to the chart in paragraph 1-3, a ____________ pound tinner's rivet should be used to rivet ________ ____________ sheets of 26-gage metal. However if two or more sheets of different thickness are to be riveted, the size of rivets is determined by the following steps. (1) The diameter of the rivet should be approximately ________ times the combined thickness of the metal. (2) The length of the rivet should be equal to the combined ________ of the metal plus ____________ times the rivet diameter. (1-8, 3)

7. What size (length and diameter) of 3003 aluminum rivets should you use to rivet a corner clip, such as shown in figure 16, if the clip is 0.040 inch thick and the standing seam is 0.020 inch thick? (1-8 and Fig. 16)

*8. After setting, upsetting, and heading, a rivet is enlarged between the two sheets of metal and the shop made head is too large and off center. Which steps were performed incorrectly? (1-14–16)

9. After setting, upsetting, and heading a rivet, you notice distortion of the sheet metal around the rivet. Which step of the riveting procedure was performed incorrectly? (1-14)

10. After completing the first two steps of the riveting procedure and the cup-shaped depression of the rivet set is placed over the upset shank, you find the shank is too large for the set. Assuming that the correct size set is being used, which step of the riveting procedure have you failed to perform properly? (1-15)

*11. What will be the result if a tinner's rivet is headed with a hand rivet set that is too large? (1-16, 17)

*12. Which step in the removal procedure for a roundhead rivet can be omitted when removing a tinner's rivet? (1-20 and Fig. 1)

13. A roundhead rivet which is installed incorrectly in a drip pan must be removed. The rivet head which you made with the rivet set is filed, center punched, and drilled; however, the drill misses the center, and the rivet hole is enlarged. Of the several mistakes made in this removal procedure, which mistake was made first? (1-20)

*14. When installing a sheet metal cover manufactured from 26-gage stainless steel on a frame of 16-gage stainless steel, a flush finish is desired but the cover is too light for countersinking. What material, head, and type of sheet metal screw is best suited for the installation? (2-2–4 and Figs. 8–10)

15. According to the chart in figure 9, what size twist drill is recommended to drill 26-gage sheet metal for a Nr. 6 type A sheet metal screw? (2-3 and Fig. 9)

*16. What advantage does a machine screw have over a stove bolt when used where there are vibrations? (2-6, 7)

17. When you are installing a 26-gage panel to a ¼-inch angle iron frame, the working drawing specifies a 10-32 machine screw and a hole that must be drilled and tapped. What size twist drill should be used? (2-7 and Fig. 13)

*18. When installing 18-gage panels on hanger doors using ¼"-28 thread bolts, what size nuts are to be used? (2-8)

19. When you are installing a metal canopy to an angle iron frame subject to jet engine blast, the working drawing specifies use of ¼"-28 thread bolts and nuts. What type of nuts would most likely be specified for the installation? (2-12)

*20. What type of nut should be used in the following situation? A large sheet metal panel is being fastened to a 1-inch flange with stove bolts. The nuts will be inside a compartment and are impossible to hold with a wrench. (2-13)

*21. Sheet metal fastening devices include such items as cleats, clips, screw nails, hangers, and braces. Enter the appropriate fastener in each of the following blanks. A ____________ is used to fasten a duct hanger to a wooden beam. A ____________ is used to connect a 90° joint. A ____________ is used to reduce vibration in a section of straight duct. A ____________ is used to align sheet metal components. A ____________ is used with sheet metal roofing. (2-14; 3-2-5)

22. During inspection of a copper roof you notice nailheads protruding through the sheeting beside several seams. What is the likely cause of this? (3-3)

23. In figure 18, part B, two types of hangers are illustrated. What advantage will hanger B (left side) have over the hanger in part A when leveling heating and air-conditioning ducts? (3-4 and Fig. 18)

CHAPTER 2

Objectives: To recognize specialized tools and machines used for cutting sheet metal, and to show a knowledge of their operation and application. To understand safety rules and maintenance procedures.

*1. If your hacksaw blade gets broken while stored in the toolbox, what is the likely cause? (4-2)

*2. Several places on the gap squaring shears, shown in figure 27, require lubricating with a few drops of oil. If this machine is in your shop, how can you determine when it was last lubricated and when the next lubrication is due? (4-10 and Fig. 27)

3. If the AF Form 1317, Maintenance Record-Equipment, for the power operated ring and circle shears in your shop does not specify what type of oil to use for lubrication, where should you look for the information? (4-10)

*4. What is the probable cause of a bent edge on a piece of sheet metal that has been cut with a pair of snips which have been sharpened, cleaned, and oiled? (5-2)

5. During inspection of a pair of hand snips you discover a half-round notch indented

in each of the blades. What misuse of the snips was the probable cause of the damage? (5-2)

6. When venting a 50-gallon hot water heater, you find the vent stack is too long and needs to be cut off 3 feet. Which hand snips or shears would be best suited for the job and why? (5-4)

*7. If your co-worker is cutting a 4-inch hole in a stainless steel hood and asks you for a pair of left-hand cut snips, what type of snips would you hand him? (5-7)

*8. If you are to stencil the cutting capacity of power shears on the holddown clamp, where would you find the rated capacity? (6-2)

9. How is the table guide of a power operated squaring shear used when you are trimming ¾ inch from the 10-inch side of a 10-inch by 16-inch piece of sheet metal? (6-5)

*10. The manually operated squaring shears, such as shown in figure 26, can be used to cut a straight line on a piece of sheet metal. If the metal slipped and the cut missed the line, what mistake was made in the cutting process? The metal was placed in the shear with the scribed line in the correct position before the treadle was operated. (6-9, 10 and Fig. 26)

11. What mistake was made in the cutting process if a piece of sheet metal is cut ¼ inch too short on one side? The production gage of the manually operated squaring shears was used properly and the holddown handles locked. (6-12)

*12. Which of the bench shears illustrated in figures 28 through 31 should you select to cut miter lines for a round Y-branch that is to be made from 16-gage metal? Your shop is *not* equipped with stationary unishears and the portable unishears are 18-gage capacity. (6-19 and Figs. 28–31)

13. If your shop is not equipped with stationary unishears, which stationary bench shears would be best suited to cut the top and bottom pieces for an offset rectangle-to-round transition that is to be made from 16-gage sheet metal? (6-19)

14. Which stationary shears would be best suited to cut a 10-foot sheet of 26-gage sheet metal into strips 6 inches wide? Your shop does *not* have gap squaring shears, circle shears, or stationary unishears, and the only squaring shears are being repaired. (6-23, 28)

*15. What is the distance from the centering pin to the cutting blade on circle shears (fig. 31) or ring and circle shears (fig. 32) if a round disc 10 inches in diameter is to be cut? (6-24, 29 and Figs. 31, 32)

*16. What is the main advantage that stationary and portable unishears have over hand snips? (6-31)

17. If you have scribed flat patterns of elbows, T-joints, and a Y-branch on a 3-foot by 10-foot sheet of 24-gage metal, what shears should you select to cut out the pieces? (6-31)

18. Which of the sheet metal cutting machines leaves the most hazardous burred edges that can cause injury to hands and fingers? (6-34)

*19. In figure 36 a hacksaw blade with 32 teeth per inch is recommended for cutting thin tubing. What *type* of hacksaw blade should be used for cutting this tubing? (7-2 and Fig. 36)

20. A piece of thin wall tubing is being sawed with a hand hacksaw that has a 32-teeth-per-inch blade. Although you are using 40 to 50 strokes per minute, the blade doesn't seem to be cutting as it should. What is wrong? (7-3)

21. Cutting oil ceases to flow from the lubricating tube of a power hacksaw, although the pump is operating and the fluid level adequate. What is the likely cause of the pump not furnishing fluid through the tube? (7-5)

*22. What type of cuts will the upright bandsaw make that the horizontal bandsaw will not make? (7-6, 7)

23. What cutting equipment should you use to cut the gores from 10-gage steel for a three-piece elbow which will be formed and welded in the welding shop? (7-6)

*24. When cutting a 3-inch diameter hole in a fire door, what saw is best suited? (7-9)

25. A job requires a $3\frac{3}{16}$-inch diameter hole which is perfectly round, has clean sides, and has no taper. A hole saw of this size is not available. What will be the most suitable cutting device for you to use? (7-10)

26. What shape and type of file should you use to remove the metal burrs from the edge of a 3-inch diameter hole which has been made with a hole saw? (8-2, 5)

*27. What should be done if a file becomes clogged with filings? (8-3)

28. What handtool is best suited to cut rusted ¼-inch stove bolts when you are removing a panel that is attached to an angle iron frame? (8-6)

29. What mistake was made in the sharpening process if the cutting edge of a chisel becomes blunt when splitting rusted stove bolt nuts? How should this mistake be corrected? (8-7)

*30. Why is it important to keep chisel heads dressed? (8-8)

31. Which abrasive wheel on a bench grinder should you use to sharpen the cutting edge of a chisel, and which abrasive wheel should you use to remove the mushroom from the chisel head? (8-9)

*32. What is the minimum safe clearance between the work rest and abrasive wheel when grinding metal $^3/_{16}$ inch thick? (8-10)

33. If your shop has just received a new grinder like the one shown in figure 44, what steps must be performed before it can be safely operated? (8-9, 10 and Fig. 44)

*34. Column 2 contains the names of 12 items of cutting equipment, and column 1 contains 12 different safety precautions. Select the appropriate number from column 2 and enter in the corresponding blank space in column 1.

Column 1

a. This item presents a safety hazard because of high speed. (8-10) ____

b. Do not operate machine if wheel and belt guards have been removed. (6-6) ____

c. This item presents a safety hazard if the ragged edges are not dressed smooth. (8-8) ____

d. Do not have foot under treadle during operation of machine. (6-13) ____

e. Improper clamping of material may cause blade to shatter. (7-5) ____

Column 2

1. Power operated squaring shears.
2. Manually operated squaring shears.
3. Utility shears.
4. All cutting machines and equipment.
5. Power operated ring and circle shears.
6. Portable unishears.
7. All electrically powered equipment.
8. Power hacksaw.
9. Bandsaw.
10. Circle cutter.
11. Chisels.
12. Grinders.

f. Return counter-balanced handle to full-up position to prevent accidental lowering of the cutting blade. (6-18) ____

g. Protect fingers and hands from burrs when handling metal that has been cut. (6-19) ____

h. Proper ground connections must be made. (6-32) ____

i. Avoid pulling the power cord across sharp or burred sheet metal edges. (6-32) ____

j. Keep clear of sheet metal as it revolves during the cutting process. (6-13) ____

k. Protect eyes when sawing. (7-8) ____

l. Material must be firmly clamped to drill press. (7-10) ____

*35. A repair job requires riveting and sweat soldering a patch on a painted tank. What tool should be used to clean the surface prior to wire brushing? (8-11)

36. What tool should you use to remove a broken gasket that is stuck to the flange surface during disassembly of a duct connection? (8-11)

CHAPTER 3

Objectives: To show a knowledge of the tools and equipment used to drill and punch holes in sheet metal. To demonstrate a knowledge of the proper use, maintenance procedures, and safety precautions of the tools and equipment.

*1. What are three causes of a twist drill becoming overheated when drilling a metal beam ½ inch thick? (9-2)

2. Why is it permissible to use a carbon steel twist drill for drilling 26-gage sheet metal with a hand drill? (9-2, 8)

3. What are two size designations of twist drills that can be used for drilling a hole 0.2500 inch in diameter? (9-3 and Fig. 46)

*4. At what angle should the lip angle of a twist drill be sharpened to drill zinc coated sheet metal? (9-4 and Fig. 47)

5. Examination of a hole reveals several long circular scratches and the hole to be ⅛ inch to the left of the intended mark. What mistake was made when preparing to drill the

hole with a high-speed twist drill and a ¼-inch portable electric drill? (9-5; 10-2)

*6. What type of drill and what size of electric drill should you use to make holes in a concrete floor for ¾-inch anchors? (9-6, 9)

7. What tools are best suited to take to the following jobs? Job A is to make four 9/16-inch holes in a concrete floor for installation of a floor stand for a grinder. Job B is to make four ½-inch holes in a cinder block building which does not have electricity. (9-6)

*8. What should you use to bevel the side of a hole in sheet metal without enlarging the diameter of the hole? (9-7)

9. What degree of bevel should the countersink have when you are installing 3/16-inch flathead stove bolts (with 80° head bevel) in 16-gage sheet metal panels? (9-7)

*10. What device should be used with a carbon steel twist drill to enlarge the corner holes of a louver being installed on the eave of a roof? (9-8)

*11. When using a portable electric drill, what safety feature should you check before operation? (9-9)

12. While inspecting twist drills for wear and breakage you discover grooves and burrs on the shank of a drill. What is the cause? (9-10)

13. While drilling holes in 16-gage sheet metal with a 3/16-inch twist drill you notice the holes are larger than 3/16 inch. What is the probable cause? (9-11)

*14. Which drilling or punching equipment discussed in this chapter creates the most dangerous eye hazard? (9-14)

15. Which electric driven drilling device is best suited to drill a 5/16-inch hole in a piece of flat bar 1¼ inches by 1 inch by 3 inches that will be tapped 1½ inches from the end? (9-14)

16. You are demonstrating the use of a drill press to another airman who has not used it before. What are two safety practices that are especially important and should be emphasized to him? (9-14)

17. In figure 51, is the drill press set up to operate at minimum or maximum spindle speed? (9-15 and Fig. 51)

*18. What adjustment should you check before using a drill press after a speed change has been made? (9-15)

19. What is the trouble if during a drilling operation the drill press spindle stops turning but the motor continues to run? (9-17)

20. What is the likely cause if the working table is hard to adjust on the column of a drill press? (9-17)

*21. When using the Whitney punch to make holes such as those shown in figure 53, what *other* punch (not illustrated) is needed? (10-2, 3 and Fig. 53)

*22. What hand punch is used when transferring paper patterns to sheet metal? (10-2)

*23. Which punch should you use to pierce ⅛-inch holes in a piece of 20-gage sheet metal? (10-3)

*24. When using a Whitney punch, such as that illustrated in figure 53, what is the maximum distance that a hole can be punched from the edge of a sheet? (10-3 and Fig. 53)

25. On a repair job, you are fabricating roof cleats with handtools. Which hold punching device would be best suited to pierce ⅛-inch nail holes in the 24-gage cleats? Why? (10-3; 3-3)

26. How can a rotary punch be used to make a slot 1 inch wide and 3 inches long with half-round ends? (10-4; 5-7; 6-21)

*27. What is the advantage of center punching a piece of metal prior to piercing a hole with a rotary punch? (10-6)

*28. What mistake was made if the hole being punched in a piece of metal by a rotary punch is $\frac{1}{16}$ inch to the left of the intended point? (10-6)

29. During inspection of a rotary punch you discover one of the punches is chipped on its edge. What is the probable cause? (10-7)

*30. Column 1 contains inspection and safety items that are checked before and during use of drilling and punching equipment. Select *one or more* of the numbers from column 2 and enter in the appropriate blank spaces in column 1.

Column 1

a. Must not be used beyond designated capacity. ____; ____. (4-6)

b. Mushrooms must be ground off of heads. ____; ____; ____. (8-8; 10-2)

c. Are sharpened to correct angle. ____; ____; ____; ____. (9-4; 10-2)

d. Power cords have proper ground connections and do not have breaks or cuts in insulation. ____. (9-9)

e. Twist drill must be secured in the chuck. ____; ____. (9-10)

f. Belt tension must be correct. ____. (9-17)

g. Correct punch and die must be in proper alignment. ____; ____. (10-3, 7)

h. Return operating handle to safe position. ____. (10-8)

Column 2

1. Hollow punch.
2. Center punch.
3. Prick punch.
4. Whitney punch.
5. Rotary punch.
6. Hand drill.
7. Drill press.
8. Twist drill.

*31. What can be used to enlarge a hole in sheet metal that is $\frac{1}{16}$ inch too small in diameter? (11-1)

*32. Which size reamer shown in figure 55 should you choose to remove the burrs from a $\frac{13}{16}$-inch hole in 18-gage sheet metal? (11-1 and Fig. 55)

33. Which reamer or rotary file should you use for a damper installation that requires two $\frac{7}{16}$-inch holes for the damper rod in a duct? You have already made starter holes for the damper rod with a ¼-inch twist drill "chucked" in a ¼-inch portable electric drill. (11-2)

CHAPTER 4

Objectives: To identify folding, forming, and seaming equipment and to show their uses and application. To understand safety rules and procedures.

*1. What is out of adjustment if a bar folder is hard to operate when bending sheet metal that is within the capacity of the machine? (13-3)

2. What three adjustments should be made on the bar folder if you are making duplicate 80° bends in 20-gage metal ⅝ inch from one edge? The bar folder was last used to bend 26-gage metal. (13-3, 4, 6)

3. What adjustment is incorrectly made on a bar folder if the desired bend is 110°, but the piece of metal being folded is 110° on one end and 115° on the other? (13-3)

4. What safety feature of a bar folder allows you to keep one hand clear of the folding blade when making a bend? (13-3, 7)

*5. How can duplicate bends of 50° be made with a bar folder? (13-6)

*6. What is the advantage of having a cornice brake sitting level on the floor when adjusting a creeping top leaf? (13-10)

*7. What are two adjustments that should be made on a cornice brake if you are going to bend 18-gage metal and the cornice brake was last used to bend 26-gage metal? (13-12, 13)

8. What adjustment was made incorrectly on a cornice brake if, while bending a piece of metal to a right angle, one end becomes 90° and the other 100°? (13-12, 18)

9. What numbered or lettered *moving* parts of the cornice brake will require lubrication? Refer to the right-hand view in figure 58. (Fig. 58)

10. What bending leaf should be installed on a cornice brake if you need to bend a smooth uniform flange that is 1¼ inches wide and 8 feet long in 22-gage sheet metal? (13-15 and Fig. 58)

11. When making ogee gutters on the cornice brake, what must be done to the brake to change over from making 90° bends to half-round bends? (13-20)

*12. Which part of the cornice brake is dangerous if it is not handled properly after a bend has been made? (13-22)

*13. What folding machine should you use to complete the forming of a container that will be 10 inches wide, 24 inches long, and 4 inches deep? The two long sides have been already formed on the cornice brake. (13-23)

14. What folding machine is best suited to form a ¾-inch standing seam on four sides of a sheet that will be used to blank (cover) the end of a square duct? (13-23 and Fig. 16)

*15. What folding machine should you use to bend a piece of ⅛-inch by 1-inch flat bar to fit around the top of a rectangular shaped pan? (13-26)

16. On the brace and wire bender the bending plate must be set back to allow for the radius of bend. What is the *minimum* distance the bending plate can be set back when bending ¼-inch round rod? (13-27)

*17. What forming machine should you use to form a round 26-gage 10-inch to 6-inch reducer that is 12 inches long? (14-4)

18. What mistake was made in using a hand operated slip roll machine if a cylinder is overformed on one end and underformed on the other? (14-4)

*19. Which roll of a power operated slip roll machine is incorrectly adjusted if the ends of a cylinder *will not* meet at the seam after the cylinder has been run through the rolls? The lower front roll is properly adjusted for the metal thickness. (14-4, 7)

20. What mistake was made when using the power operated slip roll machine to form ⅛-inch steel into a cylinder if *all but* the last 4 inches have the correct radius? The front and rear lower rolls are adjusted properly. (14-9)

*21. What should be done to the rollers on a slip roll machine if it has been used to form black iron that has a coating of rust inhibitor which came off on the rolls? (14-10)

22. If you are completing the forming of metal around wire on a funnel, what machine should you use? (14-14 and Fig. 63)

*23. What is unusual about loosening the nuts that hold the rollers on rotary machines? (14-14)

*24. The vertical distance between the rollers of a rotary burring machine are set correctly;

however, the metal is cut as it rotates between the rollers. What is the likely cause? (14-16)

25. What mistake was made when turning metal on a turning machine if the metal slips out of the rollers during the first revolution? The metal allowance was sufficient. (14-19)

*26. What rotary machine is best suited to form the V-groove for a connecting collar to the round end of a transition that has a grooved interlocking edge? (14-20)

27. A half gore has a grooved seam formed on the inside with an elbow edging machine. Where will the groove be formed on the next gore that will be connected to the half gore? (14-22, 23)

*28. What rotary machine should you use if a job requires you to join several lengths of round duct? The joints are to be reinforced and slipped inside one another. (14-28 and Fig. 68)

29. What mistake was made on the rotary crimping machine if a pipe fits too loosely inside another pipe at the joint? (14-28, 30)

*30. How can the rotary beading machine, shown in figure 69, be used to make several beads without changing the rollers? (14-32)

31. What mistake was made on the rotary beading machine if the beads *do not* meet after the first revolution? (14-32)

*32. During a duct installation, what should you use as a backer when installing the rivets in a clip which will strengthen the corner of a standing seam? (14-35)

*33. What would you use as a pattern to form a piece of metal into a desired shape if the machines in the shop *cannot* be used? (14-36)

34. What advantage and limitation will a sandbag have over a wood form block when you are forming a dish-shaped object from a sheet of copper? (14-37)

35. The end of a cylinder has been flanged with a burring machine, and the edge of a disc has been turned 90° on a burring machine. The disc has been made to fit or cap the end of the cylinder flange. What tinner's hammer should be used to fold the edge of the disc over the flange to prepare the seam for the setting down machine? (14-38, 41)

*36. What part of a tinner's hammer should you check as a safety precaution? (14-39)

*37. What is the shape of the face of a tinner's riveting hammer? Why? (14-40)

38. If you are forming two half-round copper bowls that will be soldered together to form a round tank float, what hammer should be used first, and what hammer should be used second? Why? (14-42, 43)

*39. What hammer should you use in conjunction with a sandbag to repair a dented copper bowl? (14-43)

*40. Column 2 contains inspection and maintenance items which are applicable to the various parts of a bench vise as listed in column 1. In the blank spaces of column 1, enter *one or more* appropriate numbers from column 2.

Column 1	*Column 2*
a. Jaws. ____; ____; ____.	1. Cleaned and oiled.
b. Worm gear. ____; ____; ____.	2. Grooves cleaned.
c. Base. ____; ____.	3. Excessive wear.
d. Slide. ____; ____.	4. Holddown bolts are tight.
	5. Proper action of swivel locking device.

(14-47, 48)

41. What item of sheet metal shop equipment can be used to hold a pair of hand snips still and steady while the cutting edges are being sharpened? (14-47)

*42. What will happen if a hammer or extension pipe is used to tighten the jaws of a vise? (14-48)

*43. Which side of the Pittsburg lock forming machine shown in figure 73 should you use to make the joining seams for two formed metal half patterns of a square to round transition? Why? (15-2 and Fig. 73)

*44. If the electrical power is disconnected and you have completed oiling the forming rollers on the Pittsburg lock forming machine, what safety precaution should you take before operating the machine? (15-2)

45. If you are inspecting the work of another airman who is cleaning and oiling the Pittsburg lock forming machine, what safety precaution should he perform before starting the job? (15-2)

46. What is the stretchout measurement for a 24-gage duct that will be 14 inches wide and 14 inches high and will be joined with one Pittsburg corner seam? (15-3)

*47. Which stake shown in figure 76 is best suited to back rivets when fabricating a 5-inch diameter pipe? (15-10 and Fig. 76)

48. Fill in the blanks. Assume that you are assigned to fabricate a cone-shaped funnel with a 6-inch diameter top, 1¼-inch diameter bottom, and 6 inches tall. The straight spout, 1¼ inches in diameter, is to be 4 inches long. After layout and cutting, the grooved seam is started with a ________ folder. The tapered sides are formed and seamed with a ________ stake. The wire edge is started with a ________ machine and the edge folded over the wire with a plastic or wood ________. The spout is formed and seamed on a ________ stake and soldered to the cone. (15-13; 13-2; 14-18, 46; Fig. 76)

*49. What handtool should you use to turn an edge that is too small for the cornice brake or bar folder? (15-15)

50. What handtool should you use to turn a ½-inch seam 180° on two sides of a rectangular duct so that a 3-foot addition can be made? (15-15)

51. When using a hand seamer, what should you do to insure a uniform bend which is longer than the width of the hand seamer? (15-15)

*52. A grooved seam on a fire door has been turned by hand with a hand seamer and a tinner's setting hammer. What handtool should you use to complete the setting of the seam? (15-16)

53. What handtool is suitable to fasten a 4-inch round collar if the edges have been folded back on opposite ends and hooked together after forming on the hand operated slip roll machine? (15-16)

CHAPTER 5

Objectives: To exhibit a knowledge of the operation, application, and maintenance of soldering and spot welding equipment and the use of sealants. To understand safety rules and procedures.

*1. Which of the following seams is as strong as a grooved seam: A lap seam soldered with 50/50 bar solder or a lap seam soldered with 40/60 wire solder? (16-1)

*2. If you are sent to get two pair of 3-pound fire heated coppers, what type and how many coppers will be required? (16-6, 7)

*3. Why is a fire pot more suitable than a blowtorch to heat soldering coppers if two sheet metalworkers are soldering gravel guard? (16-7, 11)

4. A roof repair job requires the soldering of several seams. What heating device would be best to use if you and another airmen are to do the soldering? Why? (16-11)

*5. If you are to repair two soldered joints on a gravel guard, which portable heating device should you use? (16-12)

6. Should you use 40/60, 50/50, or 60/40 blend of solder to seal the corners of a lead covered table top for the battery shop? Why? (16-15)

*7. Why should tools be kept away from corrosive soldering fluxes? (16-16)

8. What is the probable cause if you are having difficulty with solder not flowing properly while soldering a riveted lap seam made from new galvanized sheet metal? Why? A properly tinned and heated soldering copper is being used. (16-16)

*9. Fill in the following blank spaces with the numbered items that would be used to repair a painted grooved seam which requires resoldering.

a. What tools and equipment are required? ____; ____; ____; ____; ____; ____; and ____. (16-18, 16, 15, 11, 4, 2, and 8-11)

b. How do I prepare the tools and equipment to take on the job? ____ and ____. (16-19, 11)

c. Which articles listed involve the greatest safety hazards? ____; ____; ____; and ____. (16-16, 27, 29)

1. Scraper.
2. Wire brush.
3. Regular coppers.
4. Fire pot.
5. Muriatic acid and acid brush.
6. Fill with gasoline.
7. Clean, shape, and tin coppers.
8. Sal ammoniac.
9. 40/60 bar solder.
10. Rivet set.

10. Fill in the following blank spaces with numbered items that answer questions which may arise during the soldering of a grooved seam.

    a. What should I do to keep the soldering coppers clean during the soldering process? ______ or ______. (16-19, 20)

    b. What should I do if the solder doesn't stick to the metal? ______. (16-21, 24)

    c. What should I do if the soldering coppers are overheating between use? ______ and ______. (16-19,13)

    d. What do I do if the soldering coppers aren't heating fast enough? ______. (16-13)

    e. Why do I have to use unleaded gasoline in the fire pot? ______. (16-14)

    1. Wipe on a cotton rag.
    2. Tin the surface.
    3. To prevent clogging.
    4. Lower the heat.
    5. Increase the heat.

11. You are required to resolder a cracked seam in a cold pan which is used to hold crushed ice and to display salads in a dining hall. What should be done to make the seam ready for resoldering? (16-24)

*12. What should you do with the gasoline can after it is used to fill a blowtorch or fire pot? (16-27)

13. When working in the kitchen of a dining hall, why should you take a fire pot outside for filling with gasoline? (16-27)

*14. If you are to make a sealed spot welded joint, should the sealant be applied to the joint before or after spot welding? Why? (17-1)

15. After spot welding a joint on galvanized sheet metal, the weld pulls apart leaving jagged edges on the inner surfaces. Which settings on the spot welding machine should be checked if the current and weld time settings are properly adjusted? (17-5, 6)

*16. What is wrong with the spot welding machine if a weld pulls apart easily? The settings are all correct and the surface of the metal is clean. (17-9)

17. Which setting on a spot welding machine should be changed if the machine has previously been used to spot weld sheets of 18-gage galvanized iron and you now need to weld 0.040-inch (18-gage) aluminum? (17-12)

18. During inspection of the electrode tips on a spot welding machine you notice a shiny silvery coating on the surface. What should be done to the tips? (17-15, 18)

19. Why should you wear a face shield when assisting another airman who is operating the spot welder? You are holding the material and he is operating the upper arm and treadle. (17-17)

20. You are evaluating how well a trainee can operate the spot welding machine. He is ready to make the weld and has correctly made all of the settings on the machine; has the electrodes correctly shaped and clean; has the metal surface properly prepared; and has power, air, and water turned on. What important step has he omitted before demonstrating how well he can make a spot weld? (17-17)

*21. Why must the water lines of a spot welding machine be flushed and checked every week to 10 days? (17-18, 8)

*22. What sealant is best suited to make a riveted lap joint airtight in an aluminum duct? (18-2)

23. If you are replacing a roof ventilator on a composition shingle roof, what sealant should be used to prevent the ventilator base from leaking during rainy weather? (18-4)

24. When repairing seams on the side of a metal building that has leaked during a rain storm, what sealant should be used? (18-5)

Answers for Chapter Review Exercises

CHAPTER 1

1. The tinner's rivets in the box are 1-lb. size since 1,000 of them will weigh 1 lb. (1-3)
2. Tinner's rivets in the 2-lb. size should be used for joining two sheets of 24-gage sheet metal. (1-3)
3. Two pieces of 16-gage sheet metal should be riveted with 4-lb. tinner's rivets. (1-3 and Fig. 18)
4. The hole for a rivet with ¼-inch diameter head should be drilled or punched ½ inch from the edge of the sheet metal (two times the head diameter of the rivet). (1-7)
5. In this problem, ¾ inch is the minimum distance the centerline (center of rivet holes) can be from the edge of the sheet metal. (1-7 and Fig. 53)
6. According to the chart in paragraph 1-3, a *1* pound tinner's rivet should be used to rivet *two* sheets of 26-gage metal. However, if two or more sheets of different thickness are to be riveted, the size of rivets is determined by the following steps. (1) The diameter of the rivet should be approximately *three* times the combined thickness of the metal. (2) The length of the rivet should be equal to the combined *thickness* of the metal plus *one and one-half* times the rivet diameter. (1-8, 3)
7. The aluminum rivets should be 0.550 inch long and have a diameter of 0.300 inch. (Solution:

   0.040 " thickness of clip
   +0.060 " thickness of standing seam (3 × 0.020")
   0.100 " total thickness of clip and seam
   × 3
   0.300 " diameter of rivet required
   × 1.5 (1½ times the diameter)
   0.1500"
   +0.300 "
   0.4500" protrusion distance
   +0.100 "
   0.550 " total length of rivet shank

   (1-8 and Fig. 16)
8. Each of the three steps were performed incorrectly. (1-14–16)
9. The setting step was performed incorrectly, causing the rivet to swell between the sheets and distortion of the joint. (1-14)
10. The upsetting step was performed incorrectly as the rivet was struck too hard, causing it to spread too large to fit the cup-shaped depression of the rivet set. (1-15)
11. If an oversize rivet set is used to head a rivet, the head will be too small and malformed because it did not fill the oval-shaped cup in the rivet set. This will reduce the holding capacity of the head. (1-16, 17)
12. The filing step can be omitted since the manufactured head (of a tinner's rivet) is already flat. (1-20 and Fig. 1)
13. The first mistake was to work on the shop made head. Removal procedures should be performed only on the manufactured head of the rivet. (1-20)
14. The cover and frame are stainless steel, so a stainless steel sheet metal screw should be used; a stove head should be used to make a smooth finish, since the hole isn't to be countersunk; and type Z screws should be used, since the frame is 16 gage. (2-2–4 and Figs. 8–10)
15. A Nr. 39 twist drill is recommended for drilling 26-gage sheet metal for a Nr. 6 type A sheet metal screw. (2-3 and Fig. 9)
16. Where a vibration problem exists, machine screws with fine threads will hold better than stove bolts which have coarse threads. (2-6, 7)
17. A size 21 twist drill should be used for drilling a hole to be tapped for a 10-32 thread machine screw. (2-7 and Fig. 13)
18. ¼"-28 thread nut is used with a ¼"-28 thread bolt. (2-8)
19. Self-locking nuts would probably be specified since they are recommended where vibration is a problem. (2-12)
20. A folded spring nut can be used in hard to reach locations if the holes are near the edge of the sheet. (2-13)
21. A *screw nail* is used to fasten a duct hanger to a wooden beam. A *clip* is used to connect a 90° joint. A *brace* is used to reduce vibration in a section of straight duct. A *hanger* is used to align sheet metal components. A *cleat* is used with sheet metal roofing. (2-14; 3-2–5)
22. The likely cause is that during installation the roofer failed to turn ½ inch back over the nail heads; therefore, the nails probably have backed out and pierced the soft copper. (3-3)
23. The advantage hanger B (left side) has over hanger A is that B has threads and may be adjusted to level the duct. (3-4 and Fig. 18)

CHAPTER 2

1. Other tools in the toolbox were probably stored on top of the hacksaw, causing the blade to break. (4-2)
2. AF Form 1317, Maintenance Record-Equipment, should show the lubrication intervals and the date when last lubricated. (4-10 and Fig. 27)
3. You should consult the manufacturer's handbook or the technical manual for the ring and circle shears to determine the type of lubricating oil to use. (4-10)
4. The hinge bolt is probably loose because a sharp pair of snips should cut clean if the hinge bolt is correctly adjusted and oiled. (5-2)
5. The damage to the blades was probably caused by someone cutting wire or rod with the snips. (5-2)
6. The double cutting shears would be best suited since the joint may be cut without waste, and the sections can be crimped if necessary. (5-4)
7. Left-hand cut aviation snips. (5-7)
8. Look on the data plate for the cutting capacity of the power shears. (6-2)
9. ¾ inch can be cut from the width of the sheet metal by placing the 10-inch side against the table guide with end of the sheet even with the 9¼-inch calibration and by depressing the treadle to start the cutting cycle. (5-5)
10. The metal slipped because the holddown handles were not actuated to lock the metal sheet in the cutting position. (6-9, 10 and Fig. 26)
11. Since the machine was properly set, the mistake must have been caused by not placing the edge of the sheet metal flush against the fence. (6-12)
12. Under these conditions, the throatless shears should be your selection as they would be best suited to cut the miter lines for the Y-branch. Throatless shears will easily cut irregular lines in 16-gage metal. (6-19 and Fig. 28–31)
13. The throatless shears would be best suited since the sheet metal is 16 gage and the offset has curved lines to cut. (6-19)
14. The ring and circle shears would be best suited since they are similar to circle shears and can be set for straight slitting. (6-23, 28)
15. The distance should be 5 inches which is ½ the diameter of the disc. (6-24, 29 and Figs. 31, 32)
16. The main advantage that stationary and portable unishears have over hand snips is speed. (6-31)
17. You should select portable unishears. (6-31)
18. Unishears. (6-34)
19. A flexible type blade is recommended for cutting thin tubing and thin sheet metal. (7-2 and Fig. 36)
20. The blade is probably installed with the angle of the teeth toward the handle. (7-3)
21. The fluid strainer is probably clogged and should be cleaned. (7-5)
22. The upright bandsaw will cut irregular lines, and the horizontal bandsaw will cut only straight lines. (7-6, 7)
23. The upright bandsaw should be used to cut the gores since the lines will be irregular and the metal is heavy gage. (7-6)
24. The hole saw is best suited to cut a 3-inch diameter hole in fire doors since they are usually covered with light gage sheet metal. (7-9)
25. A circle cutter with an adjustable arm. (7-10)
26. You should use a round or half-round single-cut file to remove the burrs. (8-2, 5)
27. The filings should be removed with a file card and brush. (8-3)
28. A ½-inch cold chisel is best suited to cut ¼-inch stove bolts. (8-6)
29. Too much pressure was used and the chisel became overheated which caused the cutting edge to become soft. The soft cutting edge should be resharpened, hardened, and tempered. (8-7)
30. If chisel heads are not kept dressed, they may mushroom and cause injury to yourself or other personnel. (8-8)
31. The fine abrasive wheel should be used to sharpen the cutting edge of the chisel, and the medium abrasive wheel should be used to remove the mushroom from the head. (8-9)
32. The minimum clearance is ⅛ inch. The thickness of the metal being ground has no effect on the work rest adjustment. (8-10)
33. Before use, the new grinder should be inspected for damage and the abrasive wheel nuts checked for tightness. Then the grinder should be securely attached to a bench or stand, the work rests adjusted to ⅛-inch clearance between the wheels and work rests, the face guards adjusted to afford maximum eye protection, and the power cord plugged into a suitable electrical outlet with an approved ground. No lubrication is necessary on this particular grinder since it has sealed bearings. Now the switch should be actuated

and you should observe the grinder for excessive vibration or unusual sounds. It should be turned off immediately if vibration or noise occurs. If no defects are noted, the grinder should be allowed to run for a few minutes before use, with no personnel standing in the plane of rotation of the wheels. After turning off the switch and allowing wheels to stop, the cooling tank should be filled with water. Now, the grinder is ready for service. (8-9, 10 and Fig. 44)

34. *a.* 12. (8-10)
    b. 1. (6-6)
    c. 11. (8-8)
    d. 2. (6-13)
    e. 8. (7-5)
    f. 3. (6-18)
    g. 4. (6-19)
    h. 7. (6-32)
    i. 6. (6-32)
    j. 5. (6-13)
    k. 9. (7-8)
    l. 10. (7-10)
35. A scraper should be used to clean the paint prior to wire brushing. (8-11)
36. You should use a scraper to remove the gasket that is stuck to the flange. (8-11)

CHAPTER 3

1. Excessive overheating of twist drills may be caused by dullness, incorrect pressure, and/or failure to use a cutting oil. (9-2)
2. Because the hand drill is low speed and carbon twist drills will work satisfactorily at low speed. (9-2, 8)
3. Size E or size 1/4-inch twist drills can be used for drilling a hole which is 0.2500 inch in diameter. (9-3 and Fig. 46)
4. The lip angle should be 59° to drill the zinc coated sheet metal. (9-4 and Fig. 47)
5. The hole was not center punched which allowed the twist drill to "walk" on the metal and miss the intended mark. (9-5; 10-2)
6. A tungsten-carbide tipped masonry drill 3/4 inch in diameter that can be used with a 1/2-inch portable electric drill. (9-6, 9)
7. Tools for job A include a 3/16-inch tungsten-carbide tipped masonry drill and a 1/2-inch portable electric drill. Tools for job B include a 1/2-inch star drill and a ball peen hammer. (9-6)
8. A countersink can be used to bevel the side of a hole without enlarging the diameter. (9-7)
9. A countersink with 80° bevel should be used because the bevel of the countersink should match the bevel of the bolt head. (9-7)
10. The hand drill is best suited to enlarge the holes because the job is small and a hand drill can perform satisfactorily and quickly and can be used with a carbon steel twist drill. (9-8)
11. Portable electric drills should always be checked for proper ground connection before use. (9-9)
12. The geared chuck of the electric drill was not tightened enough to prevent the twist drill from slipping in the chuck which caused grooves and burrs to be formed on the shank of the twist drill. (9-10)
13. The twist drill is probably bent which caused the hole to be larger than 3/16 inch. (9-11)
14. The drill press would create the greatest eye hazard because usually small pieces of metal are drilled which should be securely clamped. However if the clamp should work loose and allow the piece to spin it is possible for flying pieces of metal to hit your safety glasses or face shield. (9-14)
15. A drill press should be used to drill the hole since the material can be clamped to the work table to insure correct location and alignment of the hole. Also as a safety practice, small pieces of metal should always be securely clamped during drilling operations. (9-14)
16. You should emphasize clamping material securely as well as using eye and face protective devices. (9-14)
17. The drill press is set up for maximum spindle speed because the belt runs from the largest pulley on the motor to the smallest on the spindle. (9-15 and Fig. 51)
18. The belt adjustment should be checked. (9-15)
19. The V-belt is loose and should be adjusted, or it is broken and should be replaced. (9-17)
20. The column is probably dirty or corroded which will cause the working table clamp to bind. (9-17)
21. The center punch is needed to make a small depression for the centering point of the Whitney punch. (10-2, 3 and Fig. 53)
22. The prick punch is used to transfer paper patterns to sheet metal. (10-2)
23. The Whitney punch should be your selection in this case. (10-3)
24. The Whitney punch illustrated in figure 53 can punch holes that have centers as much as 1 1/2 inches from the edge of sheet metal. (10-3 and Fig. 53)
25. The Whitney hand punch would be best suited to pierce the holes since the fabrication is away from the shop and the cleats

are small enough for the punch to be used. (10-3; 3-3)

26. The metal should be placed in the punch and 1-inch holes pierced at each end of the slot, then the rest of the material can be cut with aviation snips or scroll shears. (10-4; 5-7; 6-21)
27. Each rotary punch is made with a point which can be placed in the depression, made by a center punch, to assure accurate location of the hole. (10-6)
28. The piece being punched *must not* have been aligned properly with the center point of the punch or the center punch mark *was not* accurately made. (10-6)
29. The lockscrews holding the die in alignment have probably worked loose, allowing the die to move out of alignment with the punch. When the punch was operated in this condition the edge probably chipped as it missed the center of the hole in the die. (10-7)
30. Answers are underlined.
    a. 5; 7. (4-6)
    b. 1; 2; 3. (8-8; 10-2)
    c. 1; 2; 3; 8. (9-4; 10-2)
    d. 7. (9-9)
    e. 6; 7. (9-10)
    f. 7. (9-17)
    g. 4; 5. (10-3, 7)
    h. 5. (10-8)
31. A reamer can be used to enlarge the hole. (11-1)
32. The ¼-inch to 1¼-inch tapered reamer. (11-1 and Fig. 55)
33. Since you already have a ¼-inch portable electric drill ready to use, a ¼-inch to ⅝-inch rotary file would be a good choice to enlarge the hole for the damper rod. (11-2)

CHAPTER 4

1. The wing adjustment screws are too tight, which causes excessive clamping pressure. (13-3)
2. Adjustments to the bar folder include the thickness adjustment (wing pressure adjusting screws), width adjustment (gage adjusting screw), and angle adjustment (adjustable collar). (13-3, 4, 6)
3. The clamping pressure adjustment is made incorrectly and the wing is too tight on one end. (13-3)
4. When the operating handle is raised, the clamping pressure holds the metal securely; therefore, your left hand can be moved away from the folding blade. (13-3, 7)
5. Duplicate bends of 50° may be made with the bar folder by setting the adjustable collar to stop the wing at 50°. (13-6)
6. Proper adjustments cannot be made to eliminate a creeping top leaf condition unless the cornice brake is level because an unlevel condition can also cause creeping of the top leaf. (13-10)
7. The upper leaf and clamping pressure should be adjusted for the 18-gage metal. (13-12, 13)
8. The top leaf was adjusted incorrectly as one end is closer to the bending leaf than the other end. (13-12, 18)
9. The cornice brake shown in figure 58 will require lubrication of the following moving parts: Top shaft C, stop gage guide K, bending leaf hinge W, bending leaf hinge pin W1, and the bottom shaft 20. (Fig. 58)
10. You should install bending leaf angle bar S or SS on the cornice brake. (13-15 and Fig. 58)
11. To make ogee gutters on the cornice brake, half-round molds must be attached to the brake with clamps. (13-20)
12. The counterbalance is dangerous because of its weight which can cause injuries if the bending leaf is lowered too fast. (13-22)
13. The box and pan brake should be used to form the two short sides. (13-23)
14. The box and pan brake is best suited to form a standing seam on the four sides. (13-23 and Fig. 16)
15. The brace and wire bender should be selected because it will bend flat bar up to ⅛ inch thick and 3½ inches wide. (13-26)
16. To bend ¼-inch round rod, the bending plate must be set back at least ¼ inch, usually more. (13-27)
17. The 26-gage tapered reducer can be made on the hand operated slip roll machine. (14-4)
18. The lower rear roll was not adjusted to produce the same radius at both ends of the cylinder. (14-4)
19. The lower rear roll is not adjusted properly to form the desired diameter of the cylinder; therefore, the ends do not meet at the seam. (14-4, 7)
20. Running the metal through the power slip roll machine in only one direction was the mistake. Each end of heavy gage metal must be started in a power slip roll machine to make a perfect cylinder. (14-9)
21. The rust inhibitor should be cleaned from the rollers and the rollers wiped with an oiled rag. (14-10)
22. A rotary machine with the wiring rolls installed should be used. (14-14 and Fig. 63)

23. Some rotary machines have nuts with left-hand threads as well as nuts with right-hand threads; left-hand threaded nuts loosen to the right and right-hand threaded nuts loosen to the left. (14-14)
24. The horizontal adjustment is not correct; the distance between the side edge of the top roller does not protrude over the shoulder of the bottom roller. (14-16)
25. The metal was not held firmly against the gage as it was rotated through the rolls. (14-19)
26. The elbow edging rotary machine would be best suited since the round end is to have a grooved interlocking edge. (14-20)
27. The grooved seam will be formed on the outside of the gore that is to be connected to the half gore. (14-22, 23)
28. The crimping machine equipped with ogee beading and crimping rolls should be used. (14-28 and Fig. 68)
29. The rolls were adjusted too tight, causing the metal to be reduced too much. (14-28, 30)
30. The adjustable guide can be set at different locations so that one or more beads can be made at different distances from the edge. (14-32)
31. The metal was not held straight with the guide. (14-32)
32. A dollie should be used because the riveting is being done at a job away from the shop. (14-35)
33. Form blocks may be used as patterns to form metal into desired shapes. (14-36)
34. The sandbag is flexible and time saving. However, it is difficult to make identical objects with the sandbag. (14-37)
35. The tinner's setting hammer should be used since it is designed to set seams. (14-38, 41)
36. Hammer handles should be checked for breaks and looseness and the wedges checked for looseness. (14-39)
37. A tinner's riveting hammer has a square face with beveled edges to prevent hammer marks. (14-40)
38. A raising hammer should be used first to raise or stretch the metal, and a planishing hammer should be used second to remove dents and wrinkles. (14-42, 43)
39. A planishing hammer should be used to smooth dents and wrinkles. (14-43)
40. *a.* 1; 2; 3.
    b. 1; 2; 3.
    c. 4; 5.
    d. 1; 3.
    (14-47, 48)
41. The hand snips can be secured in a bench vise to hold them still and steady for sharpening. (14-47)
42. If a pipe or hammer is used on the handle of a vise, the jaws will be tightened too much and the worm gear damaged. (14-48)
43. The grooved side of the Pittsburg lock forming machine should be used. A grooved seam is needed because the seam is located in the middle of the component. (The Pittsburg roller side of the machine produces only corner seams.) (15-2 and Fig. 73)
44. The roller guard must be installed and lowered so that the forming rollers are covered. (15-2)
45. You should check to see if he has the electricity turned off to the Pittsburg lock forming machine. (15-2)
46. The stretchout measurement would be 57¼ inches; 56 inches for the four sides and 1¼ inches for the seam. (15-3)
47. The hollow mandrel stake is best suited because the rounded surface will make a better backing. (15-10 and Fig. 76)
48. After layout and cutting, the grooved seam is started with a *bar* folder. The tapered sides are formed and seamed with a *blowhorn* stake. The wired edge is started with a *turning* machine and the edge folded over the wire with a plastic or wood *mallet*. The spout is formed and seamed on a *conductor* stake and soldered to the cone. (15-13; 13-2; 14-18, 46; Fig. 76)
49. The hand seamer should be used to turn the edge. (15-15)
50. The hand seamer should be used to turn the seam. (15-15)
51. The adjustment screws on the hand seamer should be set so that each fold will be the same size. (15-15)
52. A hand groover should be used to complete the setting job. (15-16)
53. The hand groover is suitable to fasten the folded edges of the collar. (15-16)

CHAPTER 5

1. Neither lap seam is as strong as the grooved seam. Solder is not used for strength; it is used to seal seams and joints. The shape of solder does not change its composition. (16-1)
2. The requirement for two pair of 3-pound fire heated coppers means that you will need *four* coppers weighing 1½ pounds each. (16-6, 7)

3. Two coppers can be used while two are heating because the fire pot will heat two coppers at a time. The blowtorch will heat only one at a time. (16-7, 11)
4. The fire pot should be your choice since the two of you can solder at one time. The fire pot will heat two coppers at a time. (16-11)
5. The blowtorch should be used since the job is small and doesn't require heating two coppers at a time. The blowtorch is also small and portable. (16-12)
6. A 60/40 blend should be used to solder the corners of the lead table top covering because the high tin content allows a lower soldering temperature and there is less chance of melting the lead cover. (16-15)
7. Tools should be kept away from corrosive fluxes to prevent damage from corrosion. (16-16)
8. The probable difficulty is that not enough flux (or none at all) was applied. A flux is needed to remove the oxidation, prevent further oxidation, and lower the surface tension so the solder will flow properly. (16-16)
9. *a.* 1; 2; 3; 4; 5; 8; and 9. (16-18, 16, 15, 11, 4, 2, and 8-11)
   b. 6 and 7. (16-19, 11)
   c. 3; 4; 5; and 6. (16-16, 27, 29)
10. *a.* 1 or 2. (16-19, 20)
    b. 2. (16-21, 24)
    c. 2 and 4. (16-19, 13)
    d. 5. (16-13)
    e. 3. (16-14)
11. The seam to be resoldered must be made ready by removing the old solder, cleaning the surface, applying the flux, and tinning the surface. (16-24)
12. You should return the gasoline can to the *outside* storage. (16-27)
13. Because the open flames from the cooking equipment or sparks from electrical equipment may ignite the fumes from the gasoline. (16-27)
14. The sealant should be added afterwards because metal to be spot welded must be clean. (17-1)
15. The air pressure and hold time settings should be checked. (17-5, 6)
16. The size of the electrode tips have been overlooked. The tips are too small which weakens the weld. (17-9)
17. The current setting should be changed since aluminum requires more heat than galvanized iron during spot welding. (17-12)
18. The electrode tips should be cleaned and shaped, because the shiny silvery coating is aluminum which has alloyed with the copper tips. (17-15, 18)
19. Because the sparks can travel several feet and are hazardous to both of you. (17-17)
20. Using protective equipment such as goggles, safety glasses, and face shield. (17-17)
21. To prolong the life of the electrode tips by making sure the cooling water is clean and circulates through the electrodes. (17-18, 8)
22. Zinc chromate tape should be used since aluminum is hard to solder and the tape can be placed between the joint as the metal is lapped and riveted. (18-2)
23. An asphalt impregnated roofing cement should be used to seal the base of a ventilator on a composition shingle roof. (18-4)
24. A calking compound should be used as a sealant to waterproof the seams of a metal building. (18-5)

STOP–

1. **MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.**
2. **USE NUMBER 1 PENCIL.**

53350 02 21

REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

CHAPTER 1

1. (200) If the shank of a rivet should protrude through the combined thickness of two sheets a distance of 1½ times the diameter of the rivet, what size tinner's rivet should be used with 18-gage sheets (each 0.050 inch thick)?

   a. 2-pound.
   b. 2½-pound.
   c. 3-pound.
   d. 4-pound.

2. (200) Which one of the following sizes of tinner's rivets is recommended for riveting the corners of a drip pan fabricated from 24-gage sheet metal?

   a. The 1-pound size.
   b. The 2-pound size.
   c. The 3-pound size.
   d. The 4-pound size.

3. (200) After setting, upsetting, and heading, a rivet should look like the one illustrated in figure 6 of the text. What is the probable mistake if the edge of the shop-made head is flat instead or round?

   a. The rivet was upset too much.
   b. The rivet set was struck too hard during the setting step.
   c. The rivet set was struck too hard during the heading step.
   d. The wrong hole in the rivet set was used in the upsetting step.

4. (201) What fastening device should you use to install a duct so it will have the same height at each end?

   a. A clip.
   b. A hanger.
   c. A brace.
   d. A cleat.

5. (200) A roundhead rivet is installed incorrectly in a drip pan and needs to be removed. To do this, the rivet head which you made with the rivet set is filed, center punched, and drilled; however, the drill misses the center and the rivet hole is enlarged. Of the several mistakes made in this removal procedure, which mistake was made first?

   a. Filing.
   b. Center punching.
   c. Drilling into the manufactured head.
   d. Drilling into the shop-made head.

6. (201) If a 10–32 machine screw has stipped the threads in a tapped hole, what size twist drill should be used to make a hole to be tapped for the next larger size screw?

   a. 15.
   b. 20.
   c. 21.
   d. 26.

7. (200) How far from the edge of the sheet should the center of a rivet hole be located for a 2-pound tinner's rivet with a head diameter of 11/32 inch?

   a. 11/32 inch.
   b. 33/64 inch.
   c. 11/16 inch.
   d. 1 1/32 inches.

8. (201) What size drill shown on figure 10 of the text is needed to make a hole in 24-gage sheet metal for installation of a Nr. 6 self-tapping sheet metal screw?

   a. 30.
   b. 32.
   c. 34.
   d. 36.

9. (201) If a smooth surface is desired but the metal is too thin for countersinking, what material, head, and type of sheet metal screw is best suited for fastening a stainless steel cover to a stainless steel frame?

   a. The stainless steel, stove head, type A.
   b. The stainless steel, roundhead, type Z.
   c. The stainless steel, flathead, type A.
   d. The monel, flathead, type A.

10. (200) After setting, upsetting, and heading a rivet you notice distortion of the sheet metal around the rivet. Which step of the riveting procedure was performed incorrectly?

    a. Heading.
    b. Setting.
    c. Drawing.
    d. Upsetting.

CHAPTER 2

11. (203) What is the quickest way to trim ¼ inch from a 10¼-inch by 12¼-inch piece of metal when using power squaring shears?

    a. Use the table guide and measuring scale.
    b. Set the production gage for ¼ inch.
    c. Mark a ¼-inch line on two sides of the metal.
    d. Set the front gage at 10 inches and make the first cut, then at 12 inches and make the second cut.

12. (205) When sharpening a chisel on a bench grinder, what is the probable cause if the blade of the chisel gets red hot?

    a. Too much pressure is being used.
    b. The abrasive wheel is too fine.
    c. The abrasive wheel is too coarse.
    d. The fine wheel should be used instead of the coarse wheel.

13. (202) You are installing hangers to support a duct. What safety measures should you take before returning to the floor to move the ladder to the next hanger location?

    a. Place tools carefully in toolbox to prevent breakage.
    b. Make sure the electric drill has a proper ground connection.
    c. Make sure the ladder is resting squarely against the duct before you descend.
    d. Make sure you have all the tools you had when you went up the ladder.

14. (204) One of the views in figure 36 of the text illustrates what *not* to do. In this view, how many teeth per inch should the blade have?

    a. 14. c. 24.
    b. 18. d. 32.

15. (205) What type of file should you select to make a slot ⅛ inch longer in an angle iron bracket that is 3/16 inch thick?

    a. Single-cut. c. Under-cut.
    b. Double-cut. d. Over-cut.

16. (203) It is permissible to remove the guards from power operated squaring shears when

    a. making machine repairs.
    b. the guard interferes with the cutting operation.
    c. all personnel have become experienced operators.
    d. using the front gage and you are several feet from the cutting blade.

17. (204) What cutting device would be best to make a 5⅜-inch hole through a 26-gage metal covered roof?

    a. Roofer's hole cutter.
    b. ½-inch electric drill and hole saw.
    c. ½-inch electric drill and circle cutter.
    d. ½-inch electric drill and expansion bit.

18. (204) What cutting machine is best suited to cut a circle from a sheet of metal that is too heavy for the ring and circle shears?

    a. A power hacksaw.
    b. An upright bandsaw.
    c. A horizontal bandsaw.
    d. A stationary unishears.

19. (203) What type of shears is best suited for cutting shallow concave circles from 18-gage sheet metal?

    a. Circle shears. c. Ring and circle shears.
    b. Scroll shears. d. Throatless shears.

20. (203) What shears are best suited to cut an access hole 20 inches by 20 inches in a 20-gage duct to be installed in a building?

    a. Scroll shears. c. Throatless shears.
    b. Utility shears. d. Portable unishears.

21. (203) Which of the shears listed below would be best suited to cut corners at 45° angles?

    a. Utility shears. c. Unishears.
    b. Scroll shears. d. Throatless shears.

22. (203) What shears would be best suited to cut 3-foot by 10-foot sheets of 26-gage metal into pieces 14¾ inches by 10 feet?

    a. Ring and circle shears.
    b. Manually operated squaring shears.
    c. Utility shears.
    d. Gap squaring shears.

23. (203) Which of the following shears are best suited to cut a 3-foot by 10-foot sheet of metal into 6-inch by 10-foot pieces?

    a. Unishears. c. Utility shears.
    b. Circle shears. d. Throatless shears.

24. (203) What adjustment has been incorrectly made, when production cutting on manually operated squaring shears, if the metal is shorter on one side than the other?

    a. The side gage is not adjusted correctly.
    b. One side of the back gage is set incorrectly or has slipped.
    c. The table gage is not adjusted correctly.
    d. Allowance for the metal thickness was not made on one side when setting the gage.

25. (202) How can you be certain which type of lubricant to use when performing preventive maintenance on power squaring shears?

a. Check AF Form 1317, Maintenance Record-Equipment, manufacturer's handbook, or the technical manual for the information.
b. Check the oil cups for the type lubricant to use.
c. Check AFM 85-2, *Preventive Maintenance*, for the information.
d. Look in the oil storage cabinet and find the oil can that is marked 'Use to lubricate power shears."

26. (202) The double cutting shears are useful when installing space heaters because the cut edge may be

a. flanged.
b. crimped.
c. stretched.
d. burred.

27. (202) While installing a drain on a stainless steel cold pan that requires a 3-inch hole, what snips or shears would be best suited for cutting the hole?

a. Circle shears.
b. Double cutting shears.
c. Circle snips.
d. Aviation snips.

CHAPTER 3

28. (206) A job requires a $3\frac{3}{16}$-inch diameter hole which is perfectly round, has clean sides, and has no taper. If a circle cutter is chosen to make the hole, what drill will do the job best and with the greatest safety?

a. A ½-inch drill press.
b. A ½-inch portable electric drill.
c. A ¼-inch portable electric drill.
d. A ⅜-inch portable electric drill.

29. (206) What equipment is best suited to make $\frac{5}{16}$-inch holes 2 inches deep in a concrete wall?

a. Star drill and a ½-inch portable electric drill.
b. Carbon steel twist drill and a ¼-inch portable electric drill.
c. Tungsten-carbide tipped drill and a ¼-inch portable electric drill.
d. High-speed alloy steel twist drill and a ⅜-inch portable electric drill.

30. (206) Which drill would you be using at its rated chuck capacity to drill a 0.3750-inch diameter hole?

a. A ¼-inch portable electric drill.
b. A ⅜-inch portable electric drill.
c. A ½-inch portable electric drill.
d. A ½-inch drill press.

31. (207) If the piece of metal being punched in figure 53 of the text has several holes that are from $\frac{1}{16}$ inch to ⅛ inch off the intended location, what operation was probably overlooked?

a. The intended locations were not center punched.
b. The centerlines for the holes are too close to the edge of the sheet.
c. The wrong size punch was installed in the Whitney punch.
d. The punch and die of the Whitney punch are out of alignment.

32. (206) If specifications for a hole to be drilled are 0.2500 inch, which twist drills listed in figure 46 of the text can you use?

a. 0.2500 inch or letter F.
b. 0.2500 inch or letter A.
c. $\frac{25}{1000}$ inch or letter C.
d. ¼ inch or letter E.

33. (206) What is the decimal equivalent of a ⅛-inch twist drill?

a. 0.1200 inch.
b. 0.1230 inch.
c. 0.1250 inch.
d. 0.1270 inch.

34. (206) If the spindle of the drill press illustrated in figure 51 of the text stops turning, what is the probable trouble?

a. A slipping chuck.
b. A broken drive belt.
c. The index pin is not engaged.
d. The speed change gears are not engaged.

35. (207) When reinstalling siding that the boltheads have pulled through, which of the following punches would be most suitable to make washers that are ¼-inch inside diameter and 1½-inch outside diameter?

a. A rotary punch.
b. A hollow punch.
c. A Whitney punch.
d. An iron handlever punch.

36. (207) You are building an adjustable stand using tubing that will telescope. What tool is best suited to remove the burrs so the tubing will slide freely?

a. The twist drill.
b. The rotary file.
c. The countersink.
d. The reamer.

37. (207) What would you use to prepare holes for attaching 16-gage (1¼-inch wide) flat hangers with number 6- by ½-inch sheet metal screws to 24-gage sheet metal ducts?

   a. Ice pick or awl.
   b. 5/32-inch hollow punch.
   c. Whitney punch.
   d. A number 32 twist drill.

CHAPTER 4

38. (209) If a power operated slip roll forming machine has a capacity of ⅛-inch thickness and has an upper roll 48 inches long with a 4-inch diameter, what is the *smallest* diameter cylinder that can be formed from ⅛-inch steel 48 inches long?

   a. 4 inches.
   b. 8 inches.
   c. 12 inches.
   d. 16 inches.

39. (210) What is the stretchout measurement for an 8-inch diameter round duct that is made of 24-gage sheet metal, and the grooved seam will be made on a Pittsburg lock forming machine?

   a. 25.1328 inches.
   b. 26.1328 inches.
   c. 26.3828 inches.
   d. 26.6328 inches.

40. (209) The lower rear roll of a manually operated slip roll forming machine, when forming a 12-inch to 8-inch reducer, is adjusted

   a. the same on both ends.
   b. for a 12-inch radius and the material is fed into the rolls at an angle.
   c. for a 4-inch radius on one end and a 6-inch radius on the other end.
   d. for a 12-inch radius and the metal is slipped as it passes through the rolls.

41. (208) What folding machine should you use to form 120 feet of gravel stop and facia from 24-gage sheet metal?

   a. The bar folder.
   b. The Pittsburg machine.
   c. The cornice brake.
   d. The box and pan brake.

42. (208) What folding machine is best suited for making 8-foot sections of 24-gage rectangular duct?

   a. The bar folder.
   b. The cornice brake.
   c. The slip roll brake.
   d. The box and pan brake.

43. (208) What machine is best suited to make the first fold of a ½-inch hem for the edge of a box? The box will be made from 22-gage metal and will be 14 inches wide, 18 inches long, and 3 inches deep.

   a. The bar folder.
   b. The slip roll machine.
   c. The cornice brake.
   d. The box and pan brake.

44. (209) What is the *term* that means flattening a single seam to make it tight?

   a. Drawing.
   b. Flushing.
   c. Crimping.
   d. Setting down.

45. (209) What are two pieces of sheet metal working equipment which should be used to cut and form a panel that has several air louvers?

   a. Aviation snips and creasing stake.
   b. Utility shears and hand dolly.
   c. Double cutting shears and sandbag.
   d. Scroll shears and form block.

46. (209) Which of the following is best suited to turn an edge on a 90° rectangular elbow which will be assembled with Pittsburg lock seams?

   a. The turning machine.
   b. The beading machine.
   c. The burring machine.
   d. The elbow edging machine.

47. (209) What part of a bench vise will usually require the most cleaning and lubricating for smooth operation?

   a. Jaws.
   b. Body.
   c. Handle.
   d. Worm gear.

48. (210) What stake is best suited to set a seam in a round pipe?

   a. The creasing stake.
   b. The hollow mandrel stake.
   c. The needlecase stake.
   d. The candlemold stake.

49. (208) What is adjusted incorrectly on a box and pan brake if one of the fingers extends ⅛ inch beyond the other fingers?

   a. The finger.
   b. The upper beam.
   c. The thumbscrew.
   d. The bending leaf.

50. (209) Which of the following hammers can be considered as a finishing hammer?
   a. The raising hammer.
   b. The ball-peen hammer.
   c. The planishing hammer.
   d. The tinner's setting hammer.

51. (210) What are hand groovers used for in sheet metalwork?
   a. Flattening grooves in metal.
   b. Setting seams on riveted joints.
   c. Making grooves in flat metal for wire edges.
   d. Grooving seams that have been formed on the bar folder.

52. (210) What handtool is best suited for use on a job away from the shop to turn a ½-inch edge back 180° so a duct can be connected with an S-and-drive slip?
   a. The hand dolly.
   b. The hand seamer.
   c. The hand pliers.
   d. The hand groover.

53. (210) What part of the Pittsburg lock forming machine will usually require adjusting prior to use?
   a. The roller guards.
   b. The roller adjustment.
   c. The metal thickness gage.
   d. The seam allowance adjustment.

CHAPTER 5

54. (211) According to the textual information, what blend of solder should you use to solder a seam on a sewer gas vent roof jack which is made from a sheet of lead?
   a. 30/70.
   b. 40/60.
   c. 50/50.
   d. 60/40.

55. (211) What heating device is best suited to heat soldering coppers for soldering seams on a water tank being fabricated in the sheet metal shop?
   a. A fire pot.
   b. A blowtorch.
   c. A tinner's furnace.
   d. An electric soldering coppers device.

56. (211) If you are sent to the shop to get 4-pound fire heated coppers to solder a vertical seam in a storage tank, which of the following should you get?
   a. One 4-pound electric copper.
   b. Two 2-pound regular coppers.
   c. Three 3-pound bottom coppers.
   d. Four 1-pound fire heated coppers.

57. (212) What is the likely cause of a poor spot weld on an aluminum lap joint if the machine is set correctly and the electrodes are properly shaped and clean?
   a. Metal surfaces were not cleaned.
   b. The electrodes were inadequately cooled.
   c. The wrong flux was used when the weld was made.
   d. The aluminum is too hard for the electrodes to penetrate.

58. (211) What is the probable cause if the valve on a blowtorch is hard to open?
   a. The valve has not been oiled properly.
   b. The blowtorch has been overheated.
   c. The heated valve has contracted as it cooled.
   d. Too much pressure has been maintained in the tank.

59. (211) What would you do to soldering coppers if an inspection reveals a surface that is pitted and dark?
   a. Grind the surface.
   b. Wire brush the surface.
   c. File and tin the surface.
   d. Smooth the surface and round the corners.

60. (211) Which of the following is a safety and maintenance check for a fire heated soldering copper?
   a. Shank and handle are clean.
   b. Soldering tip is filed and tinned.
   c. Shank and handle are fastened firmly.
   d. Soldering tip is filed and shaped properly.

61. (211) Why is it a good idea to take a blowtorch or fire pot out of a dining hall for refueling?
   a. To keep the wax on the floor from being dissolved.
   b. To make ignition of the fumes less likely.
   c. To keep the fumes from contaminating the food.
   d. To hasten the evaporation of any spilled gasoline.

62. (212) What is the likely cause of a weak spot weld if the machine settings are all correct?
   a. Tips are too cold.
   b. Water in the cooling lines is dirty.
   c. Electrode tip diameters are too large.
   d. Electrode tip diameters are too small.

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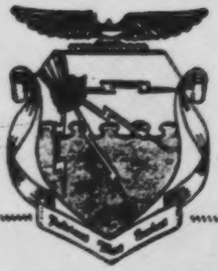
CDC 53350

SHEET METAL SPECIALIST

(AFSC's 53330 and 53350)

Volume 3

Fabrication, Installing, and Repairing Sheet Metal Components



13-1

Extension Course Institute

Air University

PREPARED BY AMARILLO AIR FORCE BASE, TEXAS, AIR TRAINING COMMAND

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE BASE, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

THIS THIRD volume of CDC 53350 is intended to "put to work" the basic facts and information you have learned in the first two volumes. By "put to work" we mean the information is job related and applies to work you are doing. The volume meets the knowledge requirements of your Job Training Standard for fabrication, installation, and repair of sheet metal components. Satisfactory completion of the chapters and review exercises will help you prepare for the Specialty Knowledge Test and will provide information on more subject areas than you are likely to encounter during the same period while training on the job.

The job-related information in this volume concerns making seams to assemble sheet metal components and making joint connections to fasten the components together. It also concerns fabricating, installing, and repairing sheet metal components of heating and ventilating systems, fixed utility equipment, roofing, gutters, and downspouts.

If you are a trainee for sheet metalworker AFSC 53330 and have completed Volumes 1 and 2 of this CDC, you should study all information contained in this volume and answer the review exercises that are identified with an asterisk (*). Then you will have completed your 3-skill-level knowledge requirements.

If you are a trainee for sheet metalworker AFSC 53350 and have completed Volumes 1 and 2 (including all chapter review exercises and volume review exercises), you should study this third volume, answer *all* review exercises, and then complete the volume review exercises before going on to Volume 4.

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Volume 3 is valued at 51 credit hours (17 points).

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Making Seams and Joint Connections

IN THIS CHAPTER we discuss several types of seams which are used to assemble sheet metal components. Some of these have been previously mentioned in other volumes of this CDC, and you are not a stranger to their purpose and use. Now you should be ready to learn how to make the various types of seams and joint connections.

2. We first discuss lap seams such as flat lap, offset lap, and corner lap. Lock seams to be discussed include grooved, double, Pittsburg, and dovetail. Joint connectors to be discussed include S-slips, drive slips, and tapped connections. We also discuss how to make pattern allowances for these seams and joint connections as well as notching, forming, and assembly.

3. Although there are other types of seams and joint connections, we have chosen to discuss only the common ones which you will more likely encounter. You need this knowledge of seams and joint connections when you fabricate, install, and repair ducts and other sheet metal components.

1. Lap Seams

1-1. A lap seam, as its name implies, is a seam or lap joint in which one piece of metal partially extends or laps over another. There are three general types: the flat lap seam, offset lap seam, and corner lap seam, which are usually joined with rivets, spot welds, bolts, or screws. Lap seams may be sealed with solder or sealing tape.

1-2. It will be necessary for you to allow extra metal to a pattern for the seam, the amount depending on the thickness of the metal and the method of fastening to be used. In Volume 1 of this CDC you learned how seam allowances are made on patterns; and in Volume 2 you learned how rivets are spaced for lap seams, how folding and forming machines are used, and how hand and bench tools are used.

1-3. **Flat Lap Seam.** The flat lap seam, shown in figure 1, is made by simply lapping one edge of sheet metal over another edge. The allowance for the lap is usually determined by the thickness of the two sheets and the method of fastening to be used.

1-4. For example, light-gage sheet metal (such as 26-gage) which is to have a riveted flat lap seam should have a ¼-inch lap. This means that the centerlines for the rivet holes should be made ¼ inch from each edge. The total amount of material allowed for a ¼-inch flat lap seam will

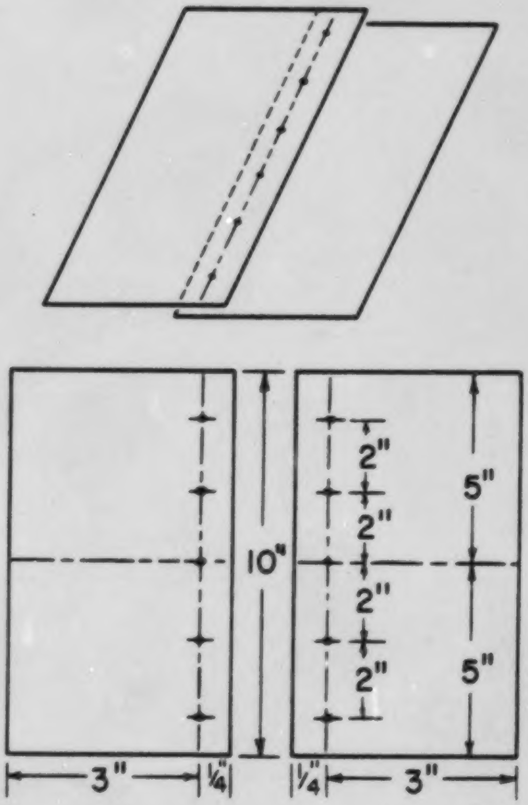

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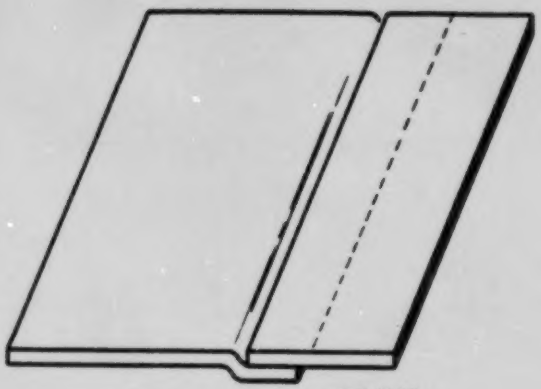
Figure 1. Riveted flat lap seam.



530-3898

Figure 2. Offset lap seam.

be ½ inch. In this case, the tinner's rivets should be the 1-pound size and should be spaced a maximum of 2½ inches apart unless otherwise specified by the working drawing.

1-5. If medium-gage sheet metal (such as 24-gage) is used, the flat lap seam should have a ⅜-inch lap; and the 2-pound tinner's rivets should be spaced a maximum of 2½ inches apart.

1-6. If heavy-gage sheet metal (such as 16-gage) is used, the flat lap seam should have a ½-inch lap and the 4-pound tinner's rivets should be spaced a maximum of 3½ inches apart.

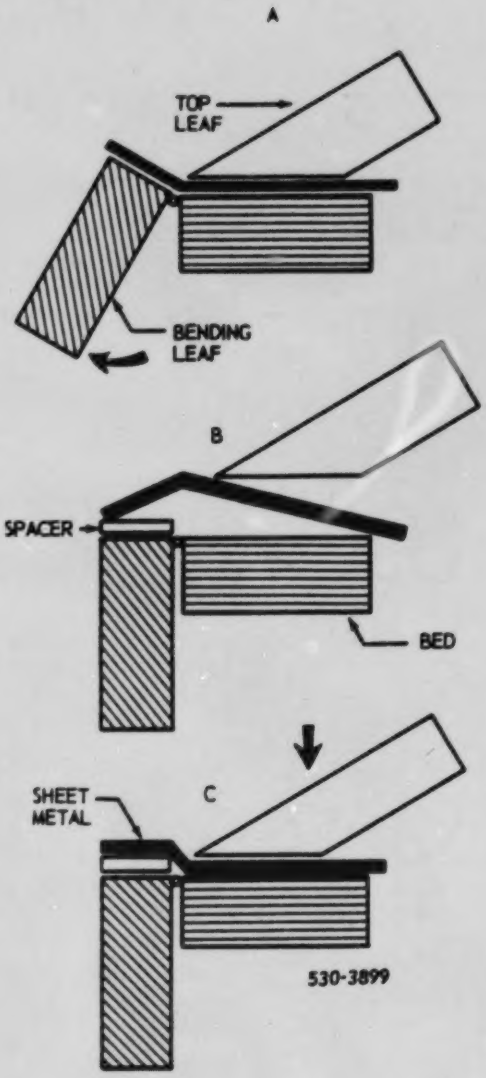
1-7. **Offset Lap Seam.** The offset lap seam, shown in figure 2, is very similar to the flat lap seam except that one edge is offset so that one sheet will be flush with the other. An offset lap seam is used in cases where the appearance of the lap needs to be as neat as possible. Seam allowances for offset seams are determined in the same manner as the allowances for flat lap seams.

1-8. The cornice brake is used to form offset bends, as shown in figure 3. Notice in step A how the bending leaf is pulled forward to make a 30° to 35° bend. In step B a spacer, with the same thickness as the desired amount of offset, is placed on the bending leaf, and the sheet metal is turned over. In step C the offset is completed when the top leaf is lowered.

1-9. **Inside and Outside Corner Lap Seams.** Inside corner lap seams and outside corner lap seams, such as those illustrated in figure 4, may be used on any gage of metal, especially on heavier gages of sheet metal. Seam allowances for inside and outside corner seams are determined in a manner similar to that for flat lap seams *except* that the allowance is made for one edge only. For example, the seam allowance for 26-gage metal is ½ inch on the folded side. In this case the centerline for the rivet holes will be ¼ inch from both edges. In figure 5 you can see how the bending leaf of a cornice brake is raised to form the 90° bend of a corner lap.

1-10. **Seam Allowances for Lap Seams.** In this section we have discussed how various types of lap seams are made and how the seam allowances are determined. Figure 6 is a chart which summarizes the seam allowance information for use with review exercises in this CDC and for a quick reference as you train on the job.

NOTE: *Because of the extent and diversity of the review exercises for this volume, we have grouped all exercises by sections. At this point,*



530-3899

Figure 3. Making an offset bend with a cornice brake.

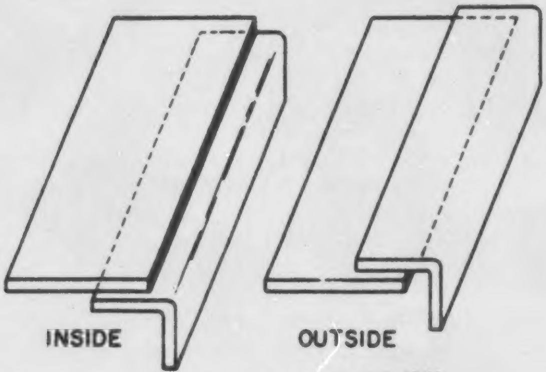


Figure 4. Inside and outside corner lap seams.

you should refer to your workbook and complete the exercises for Section 1. Then, after each succeeding section throughout the volume, you should follow the same procedure.

2. Lock Seams

2-1. In the fabrication of sheet metal components, you will use several types of lock seams, including standing seams, grooved seams, double seams, Pittsburg lock seams, and dovetail seams. These lock seams, as their names imply, lock the sheets of metal together without rivets, spot welds, bolts, or screws.

2-2. **Standing Seam.** Standing seams are used in several different ways in fabricating sheet metal components. In figure 7 you can see two views showing how the two parts (pieces 1 and 2) are assembled. Although used primarily as a means of joining two pieces of sheet metal, the standing seam also acts as a stiffener because the metal is folded three times. Standing seams are sometimes used to connect joints of rectangular duct, as stiffeners across the top and

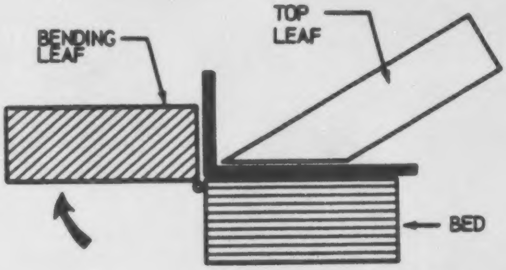


Figure 5. Making a 90° bend with a cornice brake.

Type of Seam	Gage of Metal and Decimal Equivalent	Lap Allowance (Width = W)	Size of Tinner's Rivets	Material Required		
				Formula	Side 1 or Piece 1	Side 2 or Piece 2
Flat Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Offset Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Corner Lap	26 (0.018")	1/4"	1 lb	2 X W	—	1/2"
	24 (0.025")	3/8"	2 lb	2 X W	—	3/4"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	—	3/4"
	20 (0.037")	3/8"	3 lb	2 X W	—	3/4"
	16 (0.062")	1/2"	4 lb	2 X W	—	1"

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Figure 6. Seam allowances for lap seams.

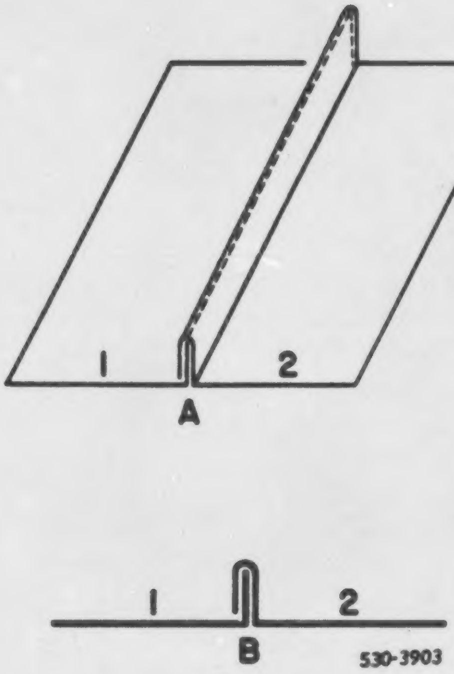


Figure 7. Standing seam.

bottom of long joints of ducts, to install covers over ends of ducts, and to connect the corners of exhaust hoods over kitchen stoves. Later in this chapter we will show you how a grooved seam and a double seam can be developed from a standing seam.

2-3. Seam allowance for a standing seam is determined by the size of the seam and the thickness of the sheet metal. For example, if a standing seam is to be made of 16-gage (0.062-inch) sheet metal and is to be 1 inch high, the seam allowance will be 3 inches plus twice the metal thickness. An easy way to remember this is by the formula 3H + 2T (using H as the height of the seam and T as the thickness of the sheet metal). In using this formula we get three times 1 inch plus two times 0.062 inch equals 3.124 inches. Remember, however, that this is the total allowance which includes both sides of the seam. The decimal 3.124, when converted to a fraction, is approximately 3⅛ inches—the total allowance for the standing seam in this example. Piece 1 of the seam will have 1 inch allowed for the 90° flange, and piece 2 will have 2⅛ inches allowed for the 180° standing fold. When fabricated, the standing seam should have flush surfaces, as shown in view B of figure 7.

2-4. The steps for making a standing seam with a cornice brake are illustrated in figure 8. Beginning with step A, you can see how piece 1 is bent 90° along the 1-inch seam allowance line. Steps B through E illustrate how piece 2 is formed. Beginning with step B, piece 2 is bent 90° on the 2⅛-inch seam allowance line. Then in step C, piece 2 is repositioned and the top leaf of the cornice brake is lowered to clamp the metal 1 inch from the end. Next, the bending leaf is swung forward and up, as shown in step D, to make a 160° bend. In step E the top leaf is lowered until the channel is reduced to the width of one thickness of metal (in this example, approximately $\frac{1}{16}$ inch). After completion of step E, the standing seam can be assembled as shown in figure 7. The two pieces should fit flush because piece 2 was folded on the 2⅛-inch line to allow for the bend.

2-5. **Grooved Seam.** A grooved seam is shown in figure 9; notice how it resembles a standing seam that has been bent over and then shaped with a hand groover. One of the main uses for grooved seams in duct construction is to join the edges of round duct joints. Grooved seams are also used for joining sheets of metal roofing and for seams *not* located in the corners of rectangular ducts. In the following paragraphs we will describe how grooved seam allowances are determined and how the seams can be made with a Pittsburg lock forming machine or with a bar folder and hand tools.

2-6. *Grooved seam allowance*. The metal allowance for a grooved seam made with a Pittsburg lock forming machine is the same as the allowance for a grooved seam made with a bar folder and handtools. As with other seams, it is necessary to allow for the width of the seam and thickness of the metal. The allowance for a grooved seam is three times the width of the seam plus the total thickness of the metal. Sheet metal which is 24 gage or lighter will require an allowance of three times the thickness, and sheet metal which is 22 gage or heavier will require an allowance of five times the thickness. Thus, the grooved seam allowance formula for the lighter gages is 3W + 3T and for the heavier gages 3W + 5T. Remember, this is the total allowance and includes both sides of the seam.

2-7. An example of making the allowance for a ½-inch grooved seam in 26-gage sheet metal will be 3 times ½ inch plus 3 times 0.018 inch. The solution will be $3 \times \frac{1}{2} + 3 \times 0.018 = 1\frac{1}{2} + 0.054 = 1\frac{1}{2} + \frac{1}{16} = 1\frac{9}{16}$ inches.

2-8. An example of making the allowance for a ½-inch grooved seam in 20-gage sheet metal will be 3 times ½ inch plus 5 times 0.037 inch. The solution will be $3 \times \frac{1}{2} + 5 \times 0.037 = 1\frac{1}{2} + 0.185$ [illegible] $1\frac{1}{2} + \frac{3}{16} = 1\frac{11}{16}$ inches.

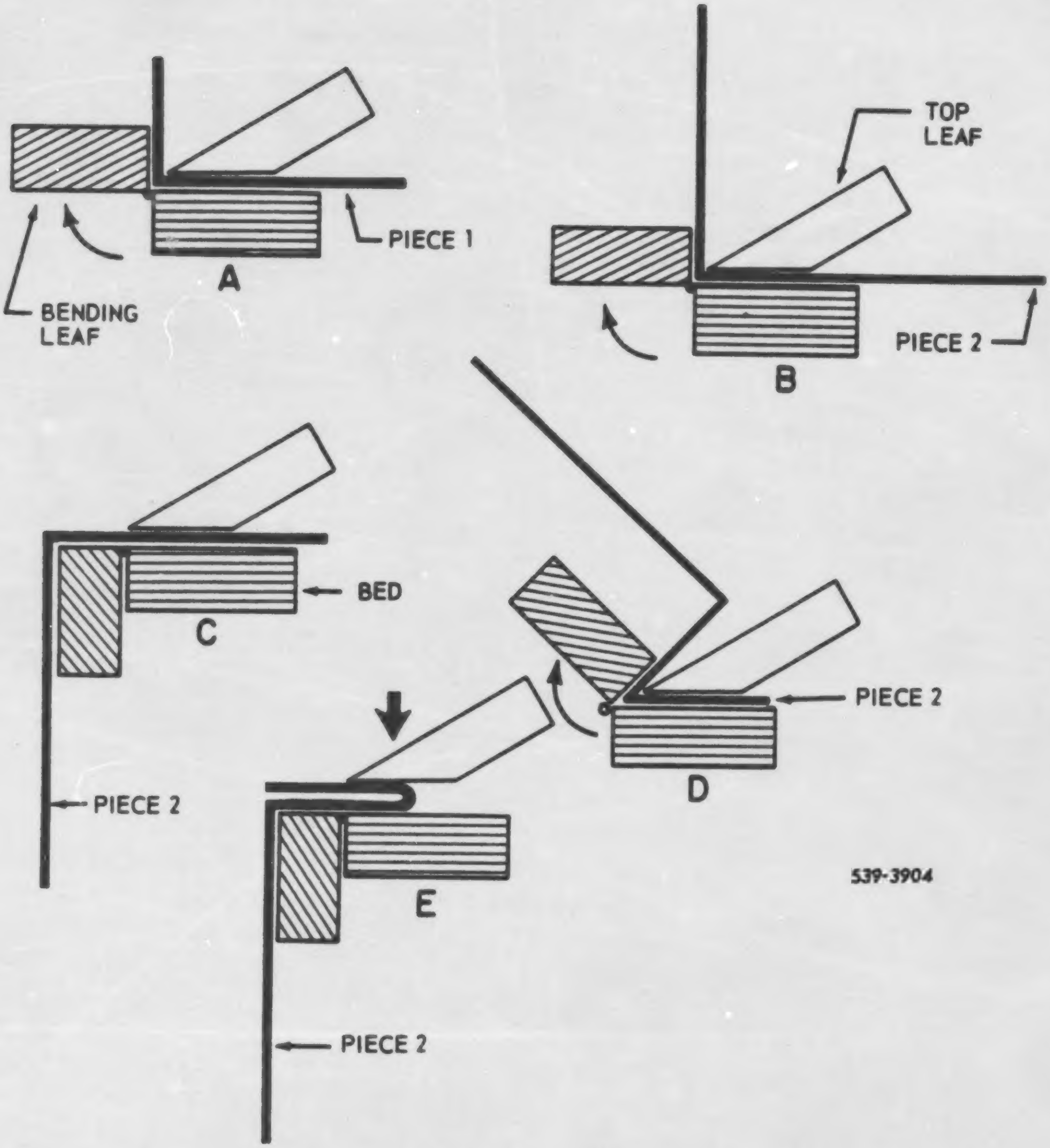

TOP
LEAF
PIECE 1
BENDING
LEAF
A
PIECE 2
B
BED
C
PIECE 2
D
PIECE 2
E
PIECE 2
539-3904

Figure 8. Making a standing seam with a cornice brake.

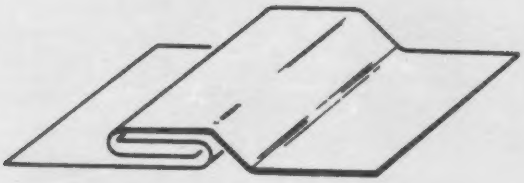


Figure 9. Grooved seam.

2-9. *Making a grooved seam with a bar folder.* Now that you have learned how to figure seam allowances, let's see how a grooved seam is made on a bar folder. (A cornice brake can also be used.) To make a ½-inch grooved seam, the depth gage of the bar folder is set for ½ inch, as you learned in Volume 2 of this CDC. The edge of the metal is placed between the frame and folding blade, and the wing is pulled forward and up to the position shown in step A of figure 10. After the wing is returned to the down position, the metal is taken out of the folder and turned over; and the wing is pulled forward and up until the folded metal is bent 180°, as shown in step B. This same procedure is used for the other half of the seam. If a grooved seam is being made on round duct or pipe, the two 180° folds are made on opposite ends of the same piece of metal but bend up at one end and down at the other.

2-10. Now look at figure 11. In step A you can see the two 180° folds that were made on the bar folder. In step B the two folded edges have been hooked together but have not been locked with a groove. In step C a hand groover is placed over the seam and struck with a tinner's riveting hammer to form the groove and lock the seam together. A suitable backing plate or bench stake must be used. The shape of the component will determine whether a flat plate or a bench stake is to be used as a backing surface. The grooved seam should be well set to prevent slipping. Sometimes it is desirable to make a series of indentations along the seam with a center punch as a further precaution against slipping.

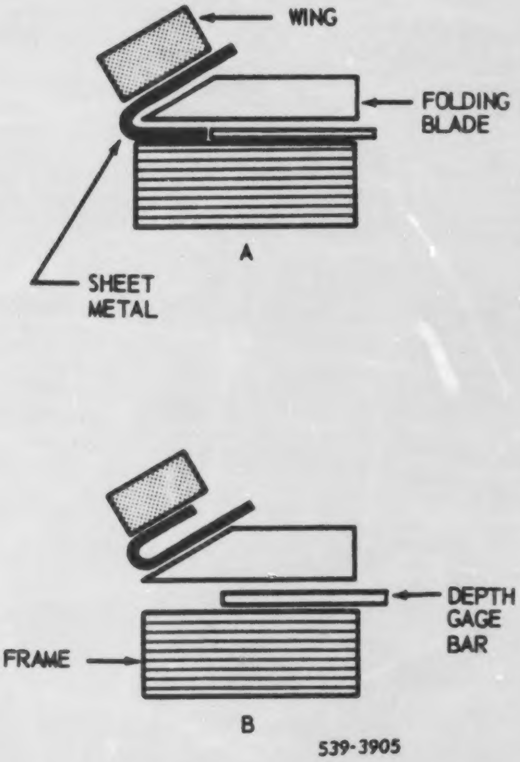


Figure 10. Making folded edges with a bar folder.

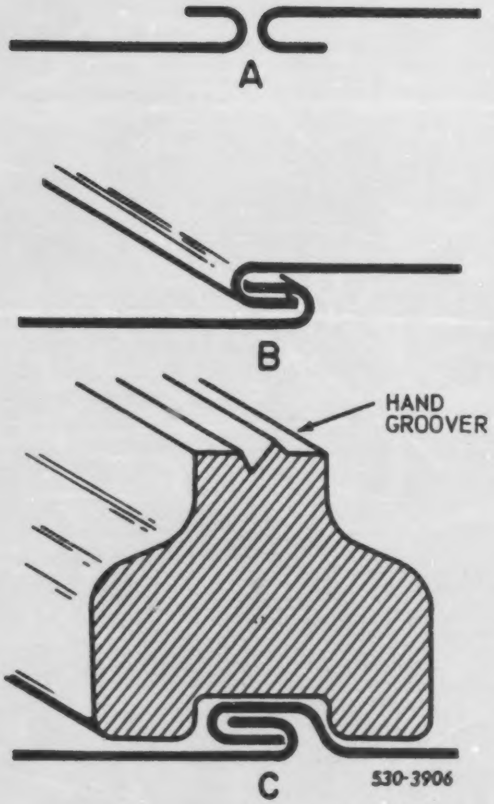


Figure 11. Making a grooved seam with handtools.

2-11. ***Making a grooved seam with a Pittsburg lock forming machine.*** Making a grooved seam with a Pittsburg lock forming machine is much easier and faster than the multistep hand method described in the preceding paragraphs. Some Pittsburg lock forming machines will make 5/16-, 3/8-, or 1/2-inch grooved seams, depending on the make and model of the machine.

2-12. After making the allowance for the grooved seam, the thickness gage on the Pitts-

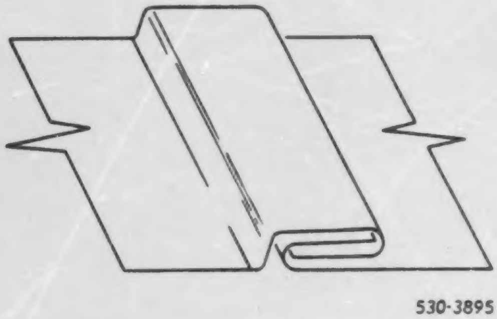


Figure 12. Grooved seam made with a Pittsburg lock forming machine.

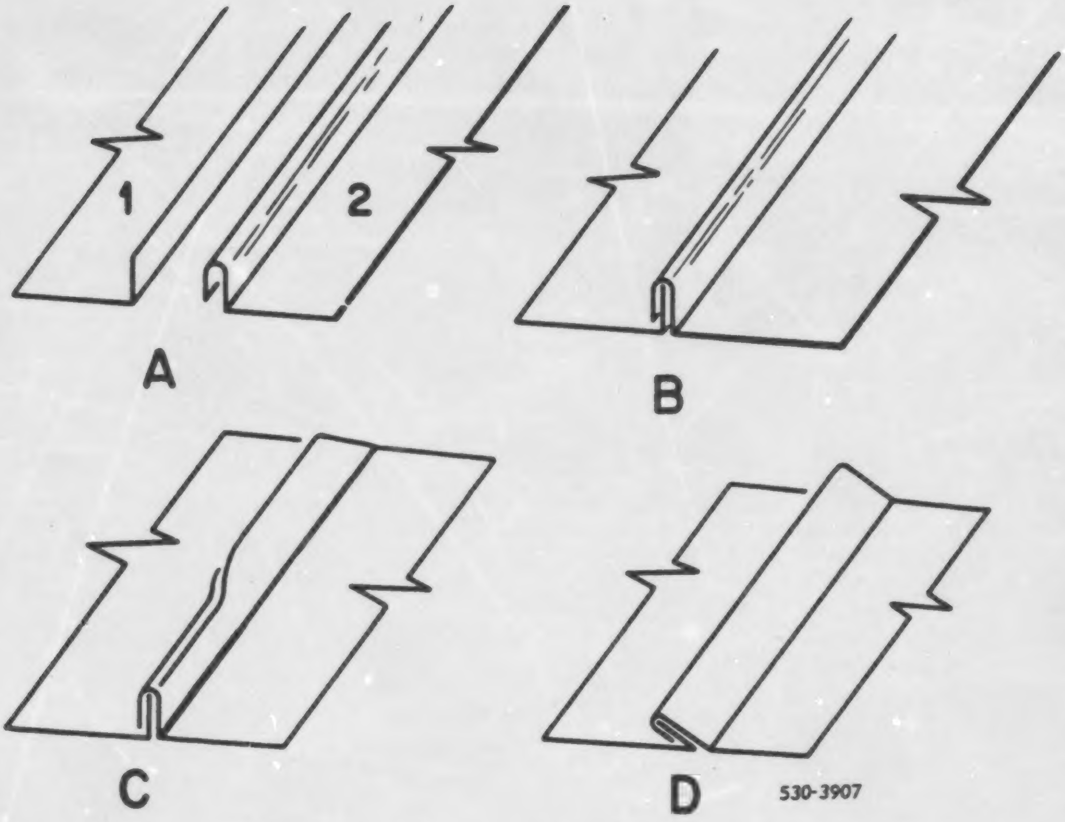


Figure 13. Making a grooved seam from a standing seam.

burg lock forming machine is adjusted to correspond to the thickness of the sheet metal. If the gage is set too loose, the result will be a loose seam. If the gage is set too tight, the metal may break at the bends. Also, if the adjustment is too tight, the machine may be damaged. After this adjustment is made, the machine is turned on and the metal is fed into the rollers. The metal should be held flush against the guide as it passes through the forming rollers. It is important to start the metal straight; once it has started through the rollers the machine will complete the operation whether it is straight or not. After two edges are folded and grooved on the Pittsburg machine, they are placed together, as shown in figure 12. The final step is to set (tighten) the assembled seam with a mallet or hammer and a suitable backing plate or bench stake. Although a grooved seam made on a Pittsburgh machine is tighter than the hand-made variety, it is sometimes desirable to center punch the seam in several places to prevent slippage.

2-13. *Making a grooved seam from a standing seam.* A grooved seam can also be made from a standing seam after the standing seam has been formed and assembled. This type of grooved seam is useful when covering flat partitions, when covering fire doors, or when making a grooved seam on a metal roof.

2-14. The metal allowance for making the seam is the same as for the standing seam which we discussed in paragraph 2-3. To make the seam, edges such as those shown in step A of figure 13 are formed. Pieces 1 and 2 are joined as shown in step B. The folding, as shown in step C, is started with a hand seamer and completed with a tinner's riveting hammer or mallet. When the seam looks like step D in the illustration, it will require grooving with a hand groover and hammer for a neat appearance and locking. A backing plate or suitable bench stake is used as a backing surface.

2-15. **Double Seams.** Two types of double seams are the corner double seam, used to seam square corners, such as square and rectangular ducts, and the bottom double seam, used to fasten bottoms on cylinders. Notice in figures 12, 14, and 15 that double seams are somewhat like the grooved seams except that they are located on the corners or edges of components.

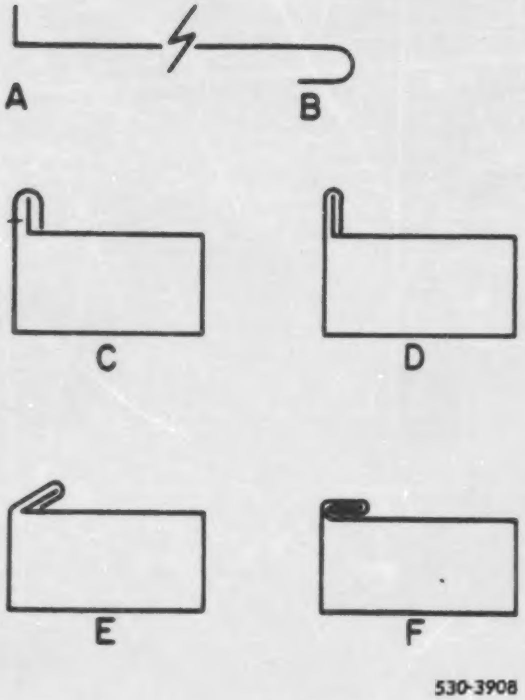


Figure 14. Making a corner double seam for articles with square corners.

2-16. *Seam allowances for double seams.* The seam allowance for forming a corner or a bottom double seam is three times the seam width plus twice the metal thickness (3W + 2T). This allowance is slightly less than for a grooved seam because the double seam is not offset. A ¼-inch double seam is often used with 28- to 24-gage sheet metal, and a ⅜-inch double seam is used with 22- to 18-gage sheet metal.

2-17. *Corner double seam.* A corner double seam can be partially made on a bar folder or cornice brake, depending on the length of the component. For example, suppose a ¼-inch double seam is to be made on a 24-gage square duct. Before the duct can be formed into a square shape, it is necessary to form the two parts of the seam which are shown in steps A and B of figure 14. If the duct joints are 20 inches or less in length, the bends for the double seam can be made on a bar folder by setting the depth gage bar for ¼ inch, bending one edge 90°, and bending the opposite edge 180° as shown in steps A and B. These bends must be made first because they would be difficult to make after the joint is formed into a square. To form the joint into a square, the cornice brake is used to bend the metal 90° along each of the three element (brake) lines. After these bends have been made, the edges are joined as shown in step C of figure 14. The next step is setting down the seam as shown in D. This setting-down operation can be done with a setting hammer or with the cornice brake. If a setting hammer is used, a backing plate or suitable bench stake must be used. In step E of the illustration, the corner

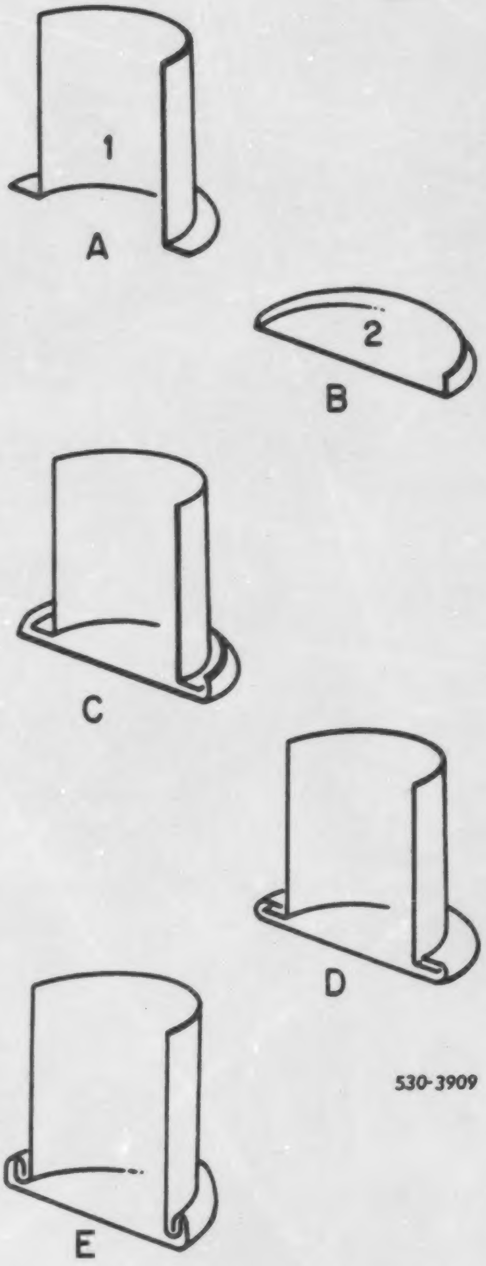


Figure 15. Making a bottom double seam for cylindrically shaped articles.

double seam begins to take shape; the seam is bent over with a mallet on the square end of a solid mandrel stake. When completely set down, the corner double seam will be like the one shown in step F of figure 14. As with other lock seams, indentations made with a center punch will prevent slippage of the seam.

2-18. *Bottom double seam.* A bottom double seam, such as that shown in figure 15, is used to fasten a bottom or end on a cylinder. The illustration shows cutaway views so that you can see the shape of the seam as it is made. As we have already mentioned, the seam allowance for a bottom double seam is three times the width of the seam plus twice the metal thickness.

2-19. Now let's see how the ¼-inch bottom double seam shown in figure 15 is made. The cylinder is identified as piece 1 in step A, and the bottom is identified as piece 2 in step B. These two pieces are the starting parts for the seam. Using the formula 3W + 2T, the seam allowance is ¼ inch for piece 1. Piece 2 will be ½ + 1/16, or 9/16 inch. A burring machine, such as you studied in Volume 2, is used to turn ¼-inch 90° flanges on both pieces. In step C the bottom is placed on the cylinder. In step D the flanged edge of piece 2 is turned down; a tinner's setting hammer or mallet is used to do this. This edge can be further tightened with a setting down machine. To complete the seam as shown in step E, a mallet and double seaming stake are used. The bottom double seam is now complete, unless it is necessary to make it liquid-tight by soldering.

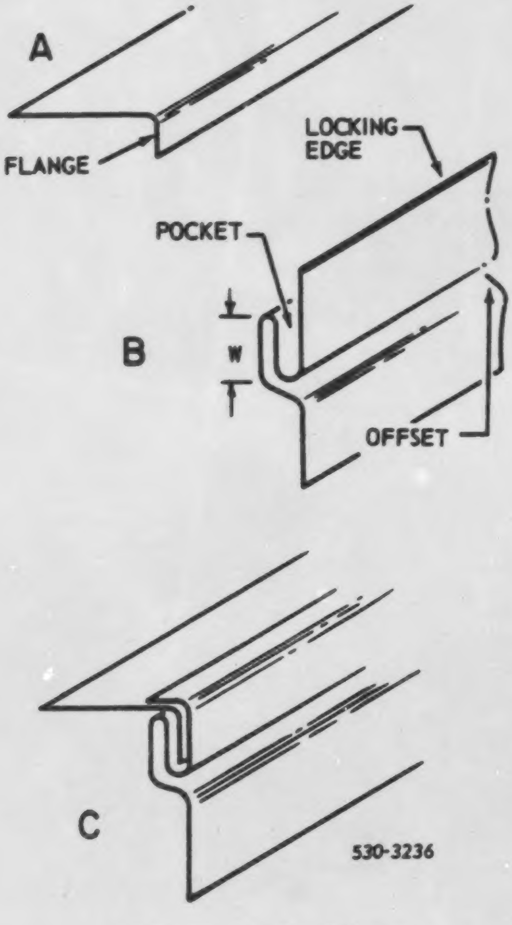


Figure 16. Pittsburg lock seam.

2-20. **Pittsburg Lock Seam.** The Pittsburg lock seam shown in figure 16 is most frequently used along one edge or corner of rectangular ducts and on all four sides of fittings such as transitions and elbows. The Pittsburg lock seam is made in two parts, as shown in views A and B. The flanged edge is usually formed on a cornice brake or on a bar folder if the joint is straight. However, if a rectangular-shaped offset or elbow is to be joined with a Pittsburg lock seam, the flanged edge is turned on a rotary burring machine, or it can be turned by hand with a round bench stake and mallet. The pocket side of the seam is made on a Pittsburg lock forming machine or a cornice brake. The seam is joined by inserting the flanged edge into the pocket and bending the locking edge, that extends above the pocket, to a 90° angle until it is locked and looks like view C of figure 16.

2-21. *Seam allowances for Pittsburg lock seams.* The allowance for a Pittsburg lock seam made with a cornice brake is different from that used when the seam is made with a Pittsburg machine. Pittsburg lock seams made with a Pittsburg machine will usually require an allowance of 15/16 inch, 1 inch, or 1 1/16 inches (depending on the make and model of the machine) for the pocket side of a seam. The flanged edge is usually ¼ inch; however, some sheet metal workers perfer a 5/16-inch flange.

2-22. The allowance for a ½-inch Pittsburg lock seam made on a cornice brake is 1¼ inches for the pocket side and ¼ inch for the flanged side.

2-23. *Making a Pittsburg lock seam with a cornice brake.* To make a Pittsburgh lock seam with a cornice brake, several steps are required. After making the seam allowance for both sides, the flanged side and the pocket side are formed by using the same procedure as the first four steps for making a standing seam, which are illustrated in figure 8. Look at step D where the metal is clamped under the top leaf and the bending leaf has been used to bend a 160° angle. To make the pocket side of the Pittsburgh

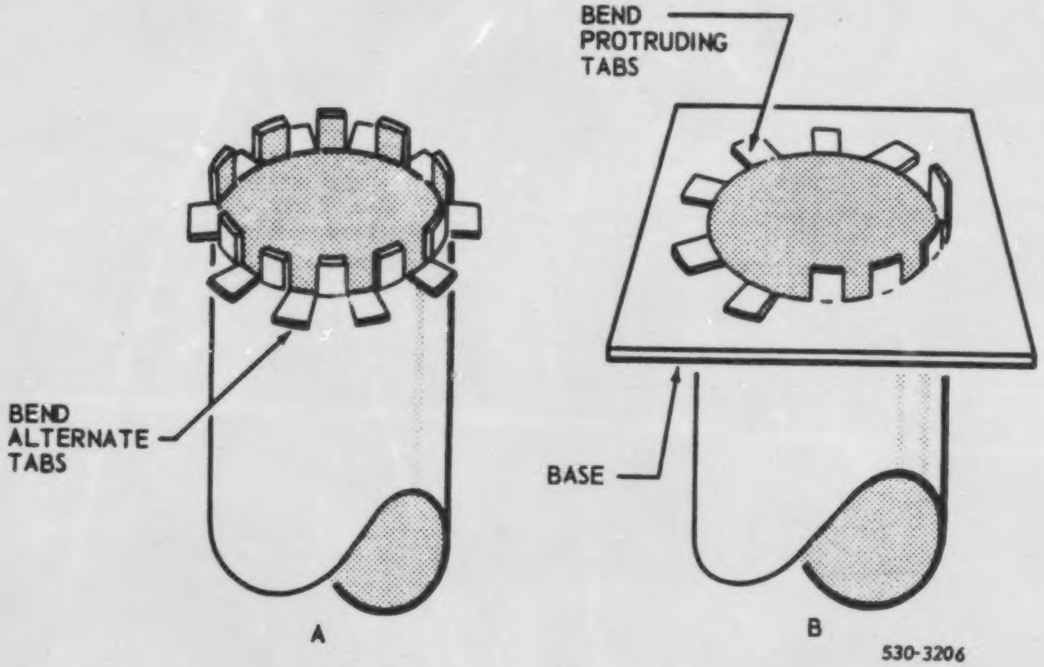


Figure 17. Dovetail seam.

seam, the bending leaf is returned to its down position, and a mallet is used to bend the 90° angle to a 180° angle. Next, the clamping pressure of the top leaf is released, and the metal is slipped back so that the top leaf can be lowered to form a tighter 180° bend similar to that in step E of figure 8. Now the metal will resemble view B of figure 16, except that the offset has not been formed. This is done by turning the metal over in the cornice brake and lowering the top leaf until a groove is formed. The final step in making the pocket side of the Pittsburg lock seam is to strike the folded metal with a mallet until the edges are parallel, as illustrated in view B of figure 16. (This sequence of bending operations is illustrated in figure 36 at the end of this chapter.)

2-24. *Making a Pittsburg lock seam with a Pittsburg lock forming machine.* When using a Pittsburg lock forming machine to make a Pittsburg lock seam, the metal thickness gage should be set according to the thickness of the metal being formed. If the gage is set too loose, a loose seam will be made; if it is set too tight, the metal may break at the bends. Also if the adjustment is too tight, the machine may be damaged.

2-25. After setting the thickness gage, the motor is turned on and the sheet metal is held flush against the guide as it is fed into the rollers. It is important to start the material straight because after it has started through the rollers the machine will complete the operation whether the metal is straight or not. As this sheet comes out of the Pittsburg lock forming machine, the open side of the pocket will be facing up.

2-26. **Dovetail Seam.** A dovetail seam, such as that illustrated in figure 17, is often used to connect cylinder-shaped ducts or pipes to flat surfaces such as the base of a roof jack. View A in the illustration shows how ½-inch square tabs have been cut and every other one bent down 90° with a tinner's hammer and bench stake. This bending operation can also be performed with a pair of common pliers. A hole the size of the cylinder is cut in the flat piece of metal which is to be the base. The base is then placed over the cylinder, as shown in view B. The remaining tabs are bent 90°. As this row of tabs is turned down, the blows from the hammer will cause both rows of tabs to tighten against the flat base.

2-27. Determining seam allowances for a dovetail seam is quite simple. The flat base does not need an allowance because the hole size is the same as the cylinder that will fit over it. The allowance for the ½-inch dovetail seam for the cylinder is the length of the tabs which are normally ½ inch in height. When cut, each tab should be ½ inch high and ½ inch wide.

2-28. If a dovetail seam is used to fasten the base of a roof jack, the seam (tabs) will be soldered in order to make a watertight seam. However, the dovetail seam is usually strong enough to hold the base securely without rivets, screws, soldering, or spot welding.

2-29. **Seam Allowances for Lock Seams.** In this section we have discussed how various types of lock seams are made and how the seam allowances are determined. Figure 18 is a chart which summarizes the seam allowance information for use with review exercises in this CDC and for a quick reference as you train on the job.

3. Joint Connectors

3-1. In this chapter you have already learned how seams are used to join pieces and corners during fabrication of sheet metal components. Now we will discuss joint connectors such as standing seams, S-slips, and drive slips which are used to connect joints of ducts or fittings.

3-2. **Standing Seams.** In paragraphs 2-2 through 2-4 of this chapter, we discussed how allowances were determined and how standing seams were fabricated. Figure 8 illustrated the steps for making a standing seam with a cornice brake. Now let's see how a standing seam is used to connect two duct joints.

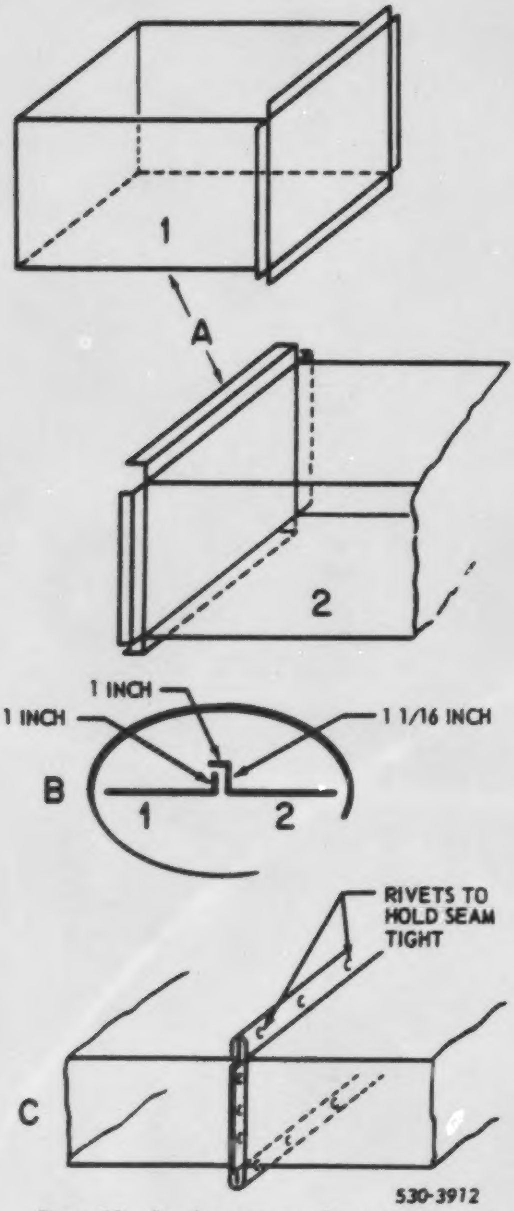
3-3. In view A of figure 19, two duct joints are ready to be connected with a standing seam. Notice that a 90° flange has been turned on all four sides of piece 1 and that two 90° angles have been turned on piece 2. View B shows the dimensions of the standing seam, view C shows how the 1-inch edge of piece 2 has been folded over the flange of piece 1 and secured with rivets. The standing seam makes a good tight joint connection but is open at the corners. These corners may be strengthened by installing corner clips. You should remember corner clips from Volume 2.

3-4. The standing seam can also be used across the center of long duct joints when two pieces

Type of Seam	Size of Seam (Width = W) (Height = H)	Gage of Metal and Decimal Equivalent	Material Required		
			Formula (Thickness = T)	Side 1 or Piece 1	Side 2 or Piece 2
Standing	1" H	24 (0.025")	3H + 2T	1"	2 1/16"
	1" H	18 (0.050")	3H + 2T	1"	2 1/8"
Grooved	1/2" W	24 (0.025")	3W + 3T	1/2"	1 1/8"
	1/2" W	20 (0.037")	3W + 5T	1/2"	1 3/16"
Corner Double	1/4" W	24 (0.025")	3W + 2T	1/4"	9/16"
	3/8" W	20 (0.037")	3W + 2T	3/8"	7/8"
Bottom Double	1/4" W	24 (0.025")	3W + 2T	1/4"	9/16"
Pittsburg Lock Made With Pittsburg Machine	—	24 (0.025")	Determined by Model of Machine	1/4" or 5/16"	1" or 1 1/16"
Pittsburg Lock Made With Cornice Brake	1/2" W	24 (0.025")	2W +1/4" +1/4"	1/4"	1 1/4"
Dovetail	1/2" H & 1/2" W	26 (0.018")	—	1/2"	—

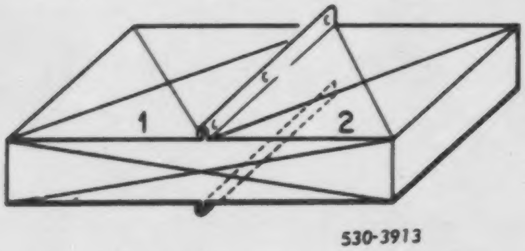
530-3910

Figure 18. Seam allowances for lock seams.


1
A
2
1 INCH
1 INCH
1 1/16 INCH
B
1
2
RIVETS TO HOLD SEAM TIGHT
C

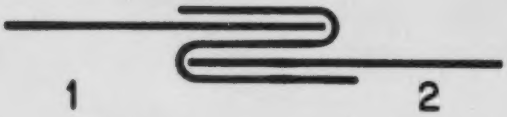
530-3912

Figure 19. Standing seams used as joint connectors.



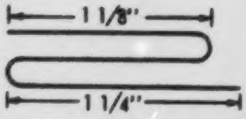
530-3913

Figure 20. Standing seam used across long joints of duct.

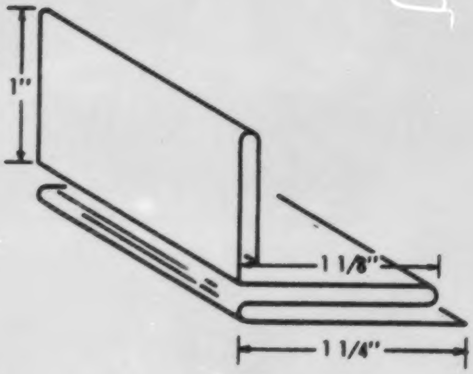


530-3914

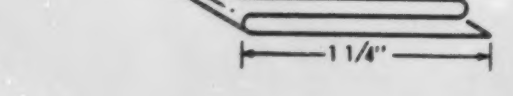
Figure 21. Flat S-slip.



FLAT S-SLIP



STANDING S-SLIP


1"
REINFORCING BAR
1 1/8"
1 1/4"

REINFORCED STANDING S-SLIP

530-3915

Figure 22. Types of S-slips.

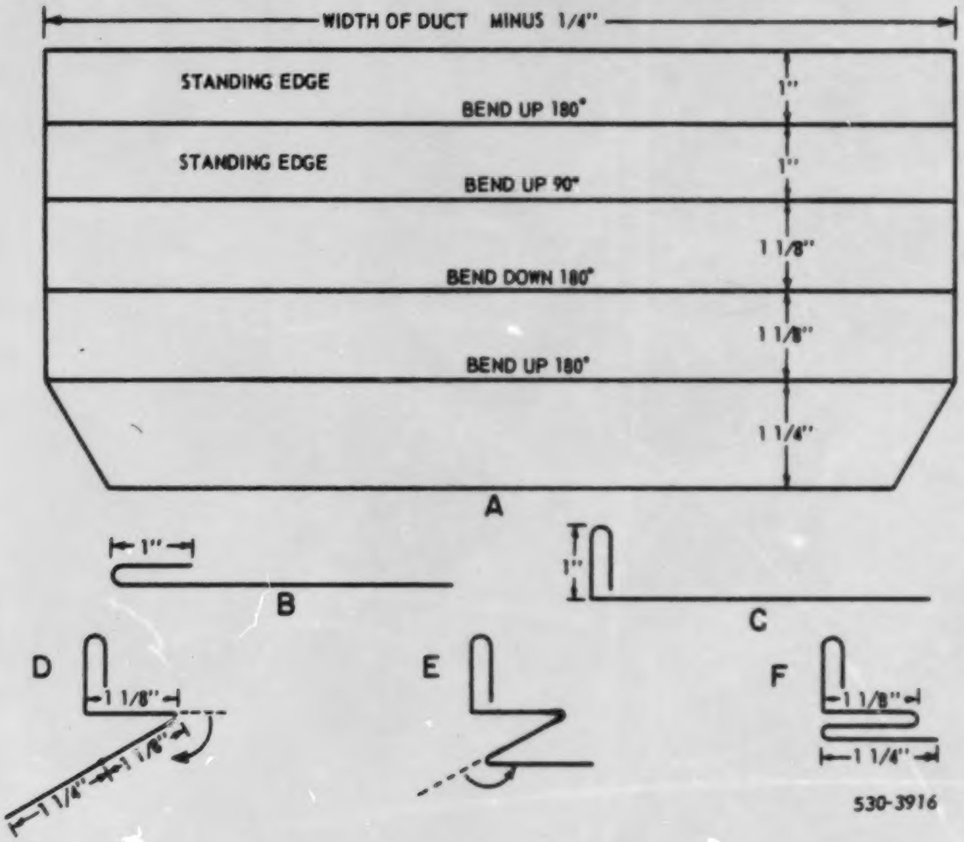


Figure 23. Making a standing S-slip.

of metal are used to make the top or bottom sides, as shown in figure 20. When used in this manner, the standing seam acts as additional bracing and allows smaller pieces to be used. Notice that piece 2 can be forced 180° before joining with piece 1. The strength added by the standing seam, the four Pittsburg corner seams, and the cross braking makes a very strong duct.

3-5. **S-Slips.** S-slips are used to join sections of ducts or fittings during the installation of duct systems. In figure 21 you can see how two pieces of sheet metal can be joined with an S-slip. When used with rectangular shaped duct, S-slips are used to connect the two sides which have the greatest width. As this width increases, the need for stiffening and bracing also increases; therefore, variations of the S-slip have been developed. Figure 22 illustrates three types: the flat S-slip, the standing S-slip, and the reinforced standing S-slip. Standing S-slips increase the strength of a duct more than a flat S-slip. A reinforced standing S-slip with its enclosed flat bar is the strongest of the three types.

3-6. *Flat S-slip.* In figure 22 you can see that the flat S-slip is the basic construction of all three types. Two parts of the S-slip are 1⅛ inches wide and one part is 1¼ inches wide. When an S-slip is constructed to these dimensions, it will allow metal to overlap 1 inch at the joint; however, don't let this be misleading as to the amount of sheet metal to be allowed when figuring the length of the duct joints. When any of these S-slips are used to join ducts, each duct should be made ½ inch longer at the end which will fit into the pockets of the S-slip. It is a common mistake to allow 1 inch for each piece being joined.

3-7. Fabricating a flat S-slip is not illustrated here but is very similar to making a standing S-slip, which is shown in figure 23. To make a flat S-slip, the standing edges are omitted from the pattern and steps B and C are not performed. The following paragraphs will clarify this explanation.

3-8. *Standing S-slip.* The standing S-slip is used in the same manner as the flat S-slip because the S-slip portion is identical. The difference is the standing edge, as shown in figure 22. This standing edge is usually 1 inch high but can range from ¾ to 1½ inches, depending on the strength required. Standing S-slips, like other S-slips, are used to join the widest sides of a rectangular duct.

3-9. Fabricating a standing S-slip is not difficult and is usually done with a cornice brake. The first step is to determine the dimensions and lay out the pattern. The pattern should look like figure 23 if standing S-slips with 1⅛-inch pockets and a 1-inch standing edge are to be made. The length of the standing S-slip should be approximately ¼ inch less than the width of the duct in order to give clearance for the corner lock seams. Notice how the 1¼-inch portion of the pattern is cut at 45° angles to make installation easier. For training purposes we have included the braking instructions on the pattern. and in steps B through F of figure 23 the directions of the bends are indicated.

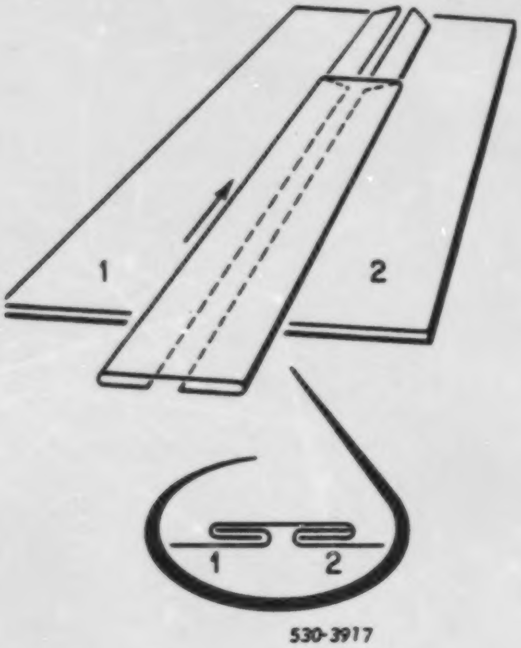


Figure 24. Drive slip.

3-10. In step B of figure 23 the standing edge is bent 180° at the 1-inch line. Next, in step C the metal is bent up 90° at the second 1-inch line. In step D the metal is turned over in the cornice brake, then bent approximately 150° at the third line between the two 1⅛-inch measurements. In step E the metal is again turned over in the cornice brake and bent approximately 150° at the fourth line between the 1⅛- and 1¼-inch measurements. In the final step (F) the two 150° bends are flattened with the cornice brake until they are each 180°.

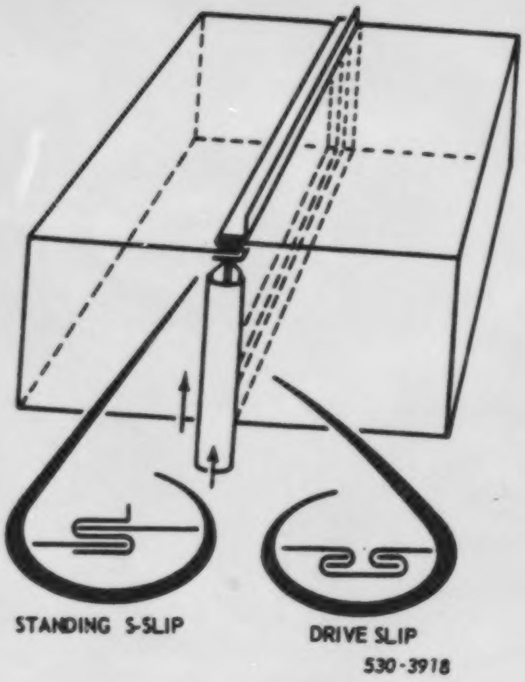


Figure 25. Duct joints connected with S-and-drive slips.

3-11. *Reinforced standing S-slip.* A reinforced standing S-slip such as that illustrated in figure 22 is similar to the standing S-slip but has a flat bar placed in the standing edge to in-

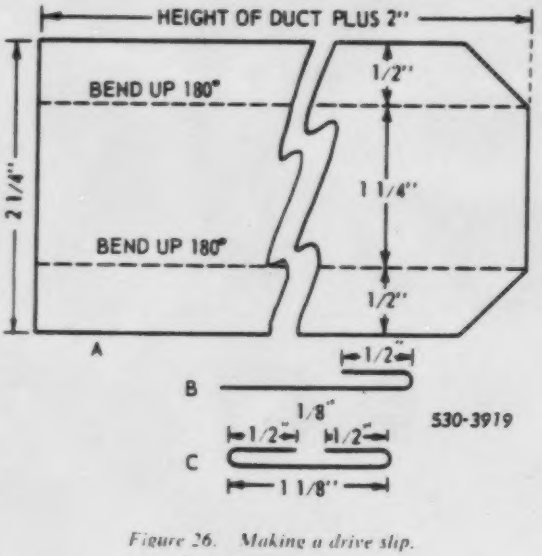
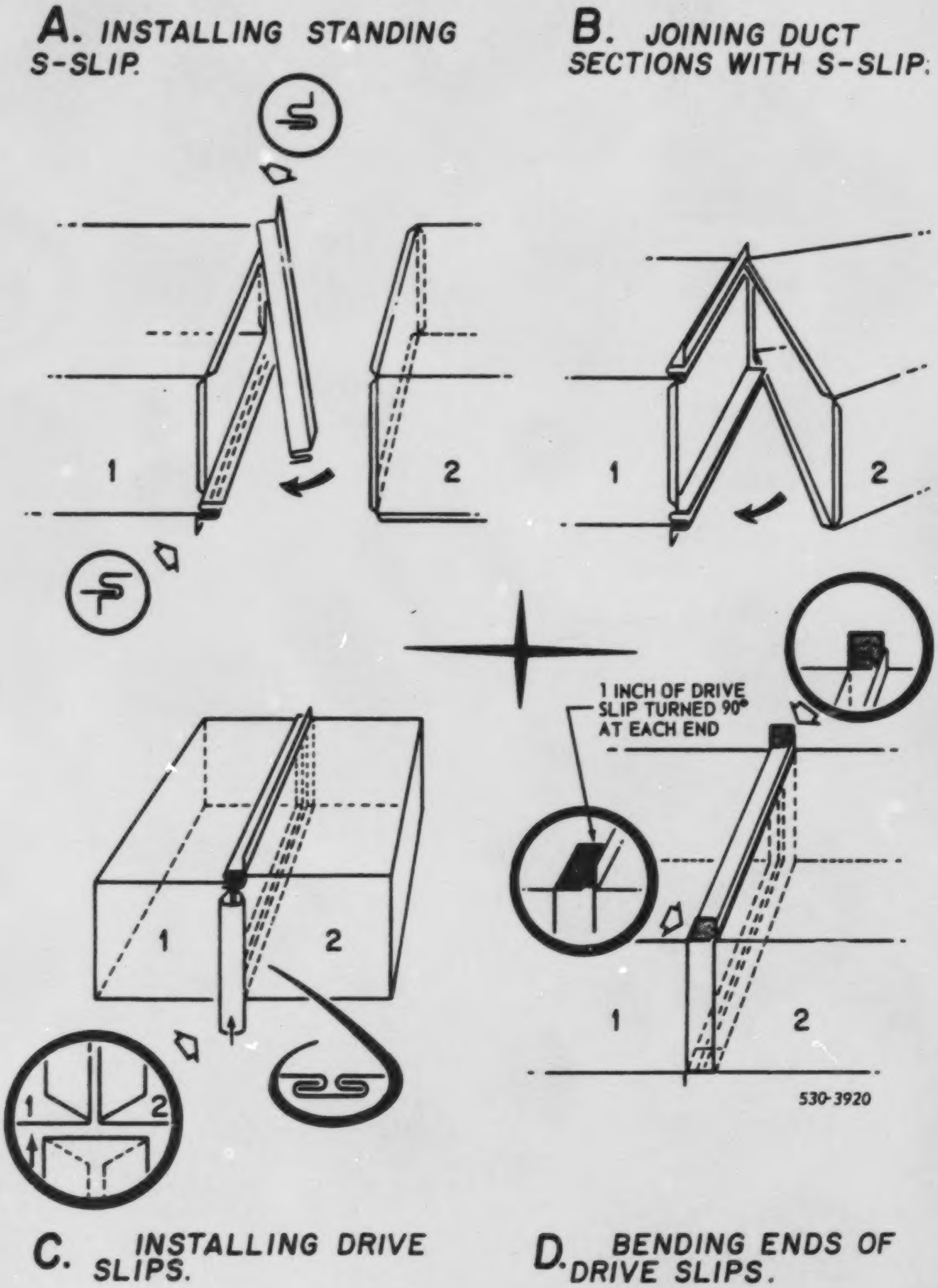


Figure 26. Making a drive slip.



A. INSTALLING STANDING S-SLIP.

B. JOINING DUCT SECTIONS WITH S-SLIP.

C. INSTALLING DRIVE SLIPS.

D. BENDING ENDS OF DRIVE SLIPS.

1
2
1
2
1 INCH OF DRIVE SLIP TURNED 90° AT EACH END
1
2
1
2
1
2
530-3920

Figure [illegible]. Connecting duct joints with S-and-drive slips.

crease the strength. The procedure for fabricating a reinforced standing S-slip is similar to making a standing S-slip as explained in the previous paragraphs. The reinforced standing S-slip illustrated in figure 23 has a 1-inch standing edge which will be reinforced with a ¾" x ⅛" flat bar. However, other widths and thicknesses of flat bar can be used if the dimensions of the standing edge are increased proportionately.

3-12. **Drive Slip.** The drive slip (sometimes called a drive cleat), illustrated in figure 24, is used as a joint connector to secure piece 1 to piece 2. Notice how the shape of the drive slip and the turned back edges of pieces 1 and 2 form a lock joint. The drive slip is installed by striking lightly with a hammer in the direction indicated by the arrow. Although drive slips can be used to connect flat sheets of metal, they are most often used (in conjunction with S-slips) to connect joints of duct. In the preceding paragraphs we said that S-slips are used to join the widest sides of the duct. Thus, it is appropriate to use S-slips across the top and bottom of the duct and drive slips on the sides, as shown in figure 25. When S-slips and drive slips are combined in this manner, the term "S-and-drive slips" is sometimes used.

3-13. Duct joints connected with S-and-drive slips are firmly locked together; however, the S-and-drive slips can be easily removed if it is necessary to dismantle the duct.

3-14. The material needed to fabricate a drive slip is determined by the width of the drive slip and the dimensions of the duct, usually the height. The first step is to lay out the pattern, as shown in step A of figure 26. This figure illustrates the often used 1⅛-inch drive slip. Notice that an extra allowance of ⅛ inch is made

ALUMINUM B&S (GAGE)	GALVANIZED IRON USS (GAGE)	WIDTH OF DUCT	TYPE OF JOINT CONNECTOR	BRACING
24	26	Up to 12"	Flat S-slips and drive slips, up to 35" centers. Standing seam or standing S-slips, up to 7'11" centers.	Cross brake
22	24	13" to 24"	Standing S-slips and drive slips, up to 35" centers.	Cross brake
22	*24	25" to 30"	Standing S-slips and drive slips, up to 7'11" centers.	Cross brake and use 1" X 1" X 1/8" angle iron or 1" standing seams on 4' centers.
22	*24	31" to 40"	Standing S-slips and drive slips, up to 7'11" centers.	Cross brake and use 1 1/2" X 1 1/2" X 1/8" angle iron or 1 1/2" standing seams on 4' centers.
20	*22	**41 to 60"	Standing S-slips (1 1/2" pocket and 1 1/2" standing reinforced edge with 1 3/8" X 1/8" bar) and drive slips up to 35".	Cross brake
20	*22	**41" to 60"	Standing S-slips (1 1/2" pocket and 1 1/2" standing reinforced edge with 1 3/8" X 1/8" bar) and drive slips up to 7'11" centers.	Cross brake and use 1 1/2" X 1 1/2" X 1/8" angle iron or 1 1/2" standing seam on 4' centers.

*For maximum strength, increase metal thickness by two gages.
** Consider hangers when using ducts this size.

530-3921

Figure 28. Joint connectors, metal gages, and bracing recommended for sheet metal duct.

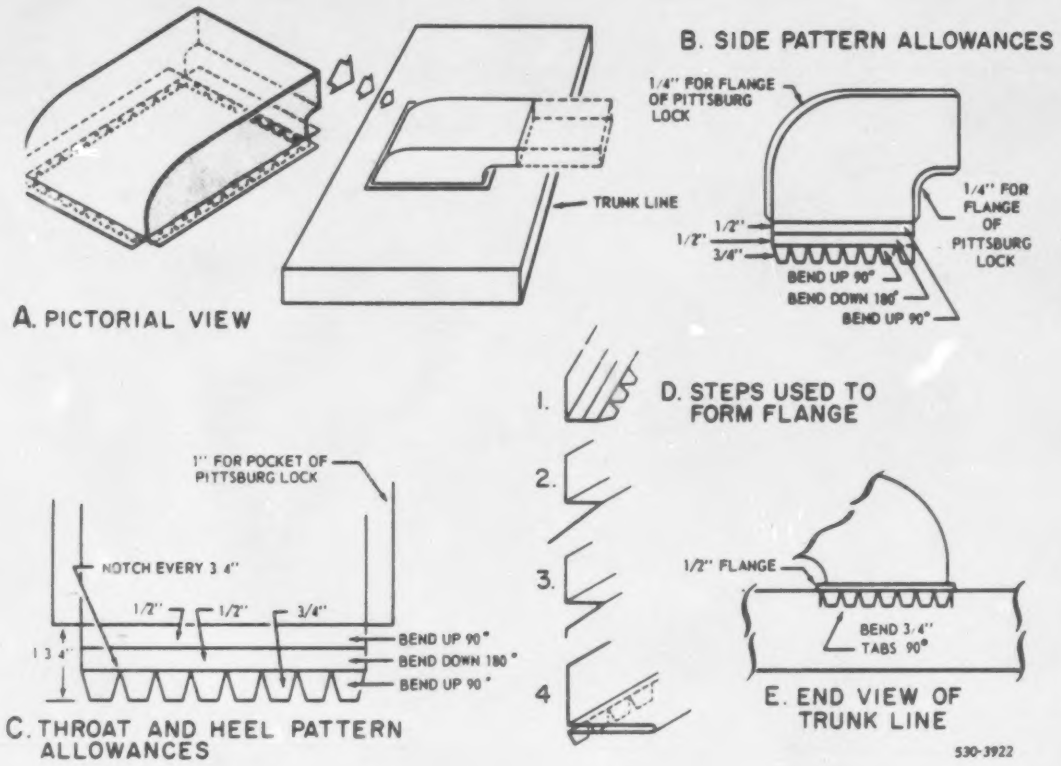

A. PICTORIAL VIEW
TRUNK LINE
B. SIDE PATTERN ALLOWANCES
1/4" FOR FLANGE OF PITTSBURG LOCK
1/4" FOR FLANGE OF PITTSBURG LOCK
1/2"
1/2"
3/4"
BEND UP 90°
BEND DOWN 180°
BEND UP 90°
1.
2.
3.
4
D. STEPS USED TO FORM FLANGE
1" FOR POCKET OF PITTSBURG LOCK
NOTCH EVERY 3/4"
1/2"
1/2"
3/4"
1 3/4"
BEND UP 90°
BEND DOWN 180°
BEND UP 90°
C. THROAT AND HEEL PATTERN ALLOWANCES
1/2" FLANGE
BEND 3/4" TABS 90°
E. END VIEW OF TRUNK LINE
530-3922

Figure 29. Making a tapped connection for a curved takeoff fitting.

on the center section to allow easier installation. If the drive slip is being made for an 18- x 12-inch duct, the drive slip should be made 14 inches long so that 1 inch will extend past each end and can be bent down to keep the drive slip in place.

3-15. After the pattern has been made, the metal is cut and the bar folder is used to turn each edge 180° along the brake lines, as shown in steps B and C of figure 26. With 45° angles cut at one end, the drive slips can be installed with less effort. When completed, the 1⅛-inch drive slip should have dimensions and appearance as shown in step C.

3-16. **Installing S-and-Drive Slips.** Figure 27 illustrates the complete process of using S-and-drive slips to connect joints of duct. View A shows standing S-slips being installed on the top and bottom sides of a duct joint. Notice how the top S-slip is started at a 45° angle because the channels usually form a tight fitting. After the S-slip is started at one end, it can be tapped into place with a hammer or mallet until it is in the same position as the bottom S-slip in the illustration. Notice the position of the standing edges of the top and bottom S-slips. Figure 27 also shows the allowance for the overlap of joints 1 and 2. This allowance is ½ inch on each edge when 1⅛-inch S-and-drive slips are used. The additions on both joints have been notched 45° at the corners.

3-17. View B of figure 27 shows how joint 2 is inserted at one end into the S-slip. Next, joint 2 is firmly moved in the direction of the arrow until all of the top and bottom joint addition is inserted into the pockets of the S-slips. Now joints 1 and 2 should be in perfect alignment; however, the two S-slips will not lock the joint. The next step is to install the drive slips on the sides of the duct to lock the joints together.

3-18. View C of figure 27 shows how a drive slip is being inserted over the turned back edges of the two joints. The drive slip should drive on easily with light taps of a hammer if the patterns were correctly made and the edges turned properly. When both drive slips are installed, the two joints are firmly held together. However, one more step is taken to insure that the drive slip does not come off.

3-19. View D in figure 27 shows how the extra 1 inch, which was added to each end of the drive slip, is turned down to form a positive lock. This operation completes the connection of two duct joints with S-and-drive slips. This is an excellent connection and has the additional feature of being easy to disconnect if at some future date the duct should need to be dismantled.

3-20. **Joint Connectors, Gage of Metal, and Bracing Recommended for Sheet Metal Duct Construction.** Since joint connectors and bracing may be fabricated in the sheet metal shop (as described in the preceding paragraphs), it may become necessary to determine what type of construction is appropriate to the duct system being fabricated. Since standing S-slips are stronger than flat S-slips and reinforced S-slips are stronger than standing S-slips, we have included a chart (fig. 28) to show the gages of metal, types of

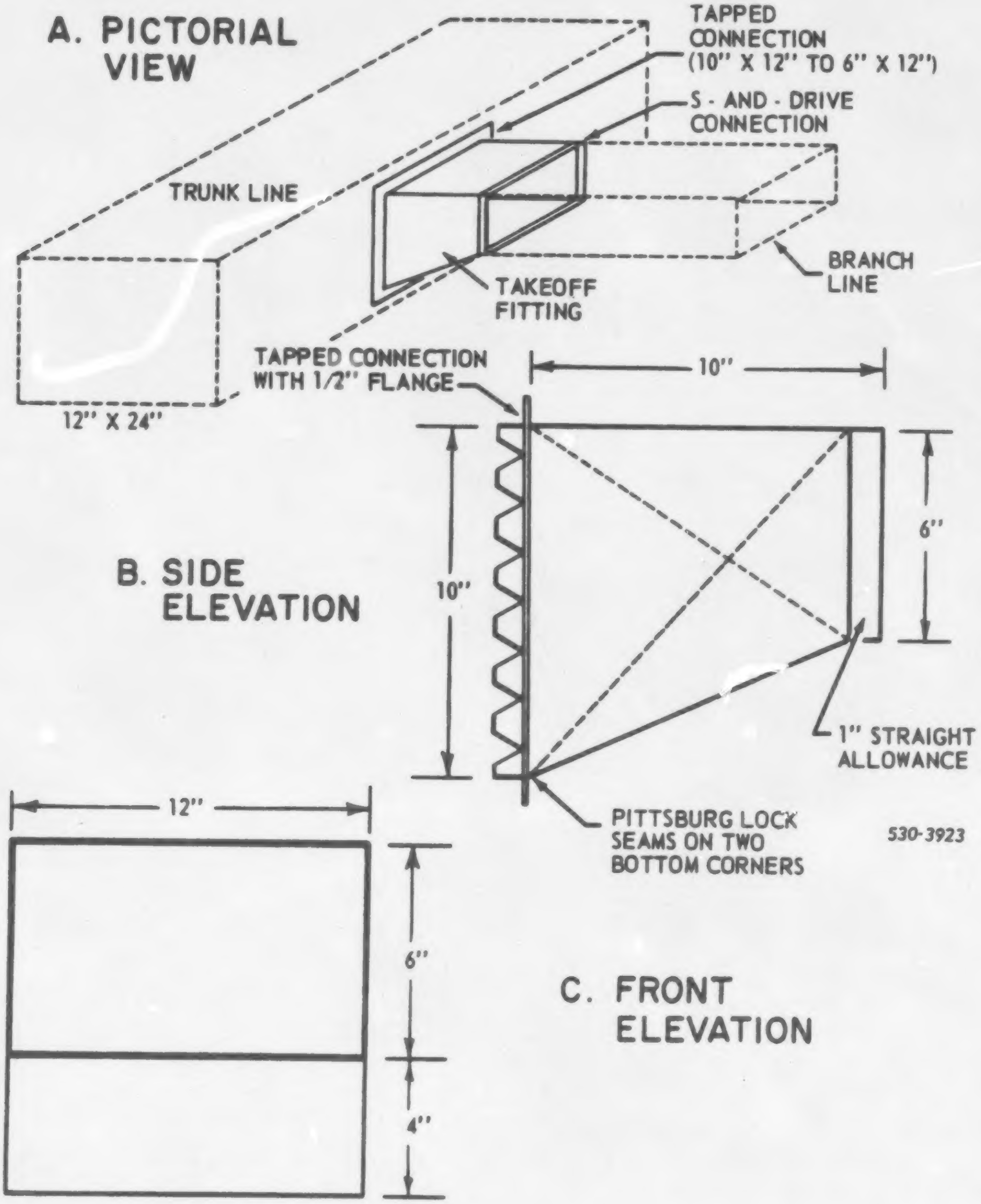
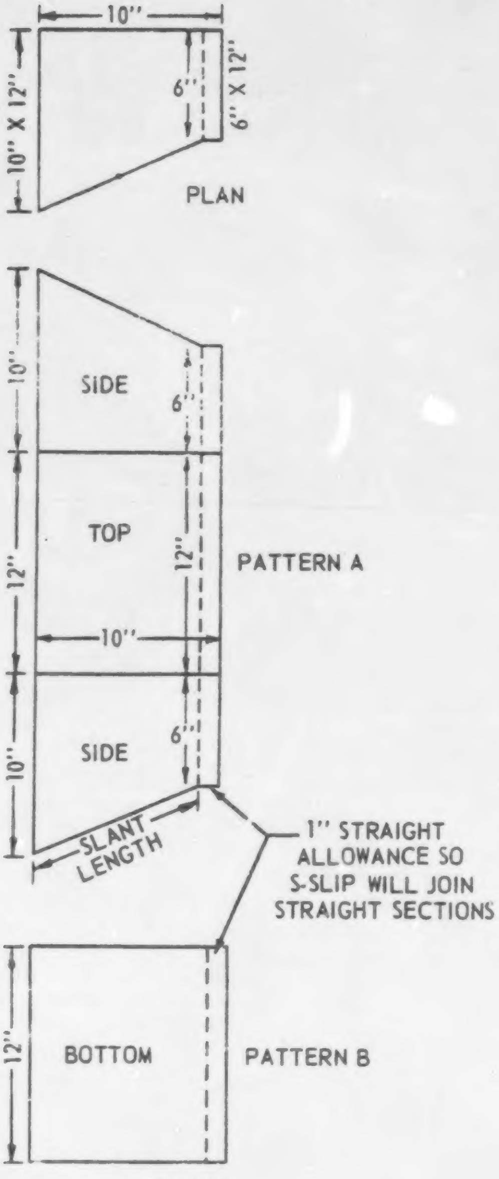

A. PICTORIAL VIEW
TAPPED CONNECTION (10" X 12" TO 6" X 12")
S - AND - DRIVE CONNECTION
TRUNK LINE
BRANCH LINE
TAKEOFF FITTING
12" X 24"
TAPPED CONNECTION WITH 1/2" FLANGE
10"
B. SIDE ELEVATION
10"
6"
1" STRAIGHT ALLOWANCE
PITTSBURG LOCK SEAMS ON TWO BOTTOM CORNERS
530-3923
12"
6"
4"
C. FRONT ELEVATION

Figure 30. Tapped connection on a tapered takeoff fitting

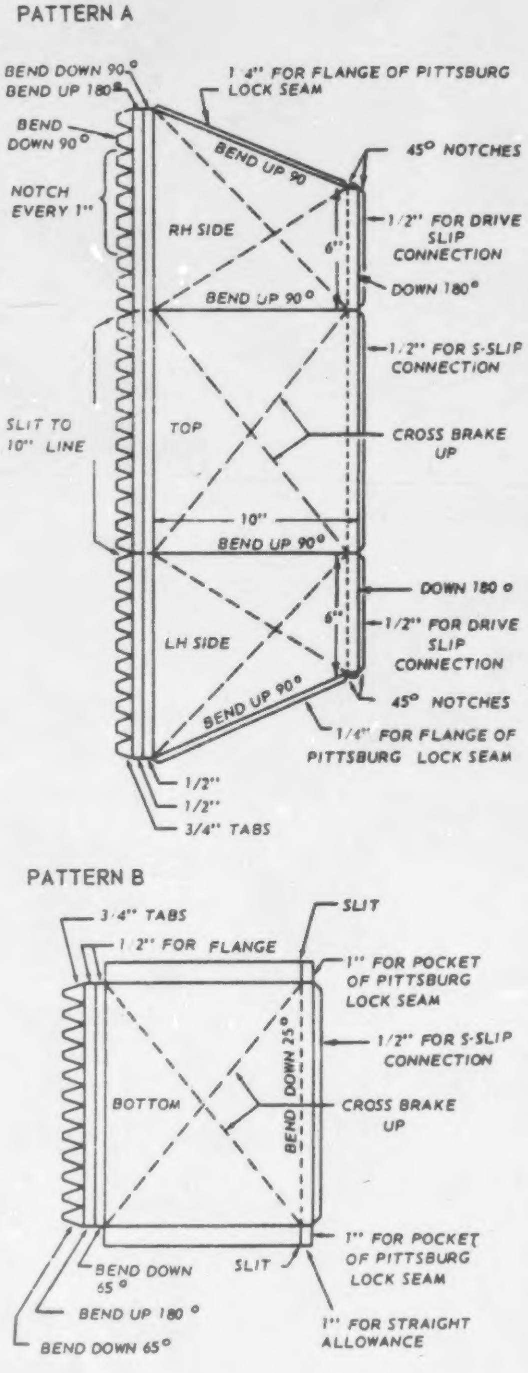

10"
10" X 12"
6"
6" X 12"
PLAN
10"
SIDE
6"
12"
TOP
12"
PATTERN A
10"
10"
SIDE
6"
SLANT LENGTH
1" STRAIGHT ALLOWANCE SO S-SLIP WILL JOIN STRAIGHT SECTIONS
12"
BOTTOM
PATTERN B

530-3924

Figure 31. Patterns for takeoff fitting.

joint connectors, and type of bracing recommended for various sizes of sheet metal ducts.

3-21. Notice in figure 28 that the thickness of aluminum is measured in B&S gage (Brown and Sharp), which is recognized as standard in the United States for wire and sheet metal not made of iron or steel. Galvanized sheet iron is measured with USS gage (US Standard). When a coating, such as zinc, is applied to sheet iron or steel to form galvanized sheet metal, the mate-


PATTERN A
BEND DOWN 90°
BEND UP 180°
1/4" FOR FLANGE OF PITTSBURG LOCK SEAM
BEND DOWN 90°
BEND UP 90
45° NOTCHES
NOTCH EVERY 1"
RH SIDE
6"
1/2" FOR DRIVE SLIP CONNECTION
DOWN 180°
BEND UP 90°
1/2" FOR S-SLIP CONNECTION
SLIT TO 10" LINE
TOP
CROSS BRAKE UP
10"
BEND UP 90°
DOWN 180 °
6"
1/2" FOR DRIVE SLIP CONNECTION
LH SIDE
45° NOTCHES
BEND UP 90°
1/4" FOR FLANGE OF PITTSBURG LOCK SEAM
1/2"
1/2"
3/4" TABS
PATTERN B
3/4" TABS
SLIT
1/2" FOR FLANGE
1" FOR POCKET OF PITTSBURG LOCK SEAM
1/2" FOR S-SLIP CONNECTION
BEND DOWN 25°
BOTTOM
CROSS BRAKE UP
1" FOR POCKET OF PITTSBURG LOCK SEAM
BEND DOWN 65°
SLIT
BEND UP 180 °
1" FOR STRAIGHT ALLOWANCE
BEND DOWN 65°

530-3925

Figure 32. Making allowances for S-and-drive slip connections, Pittsburg lock seams, and tapped connection.

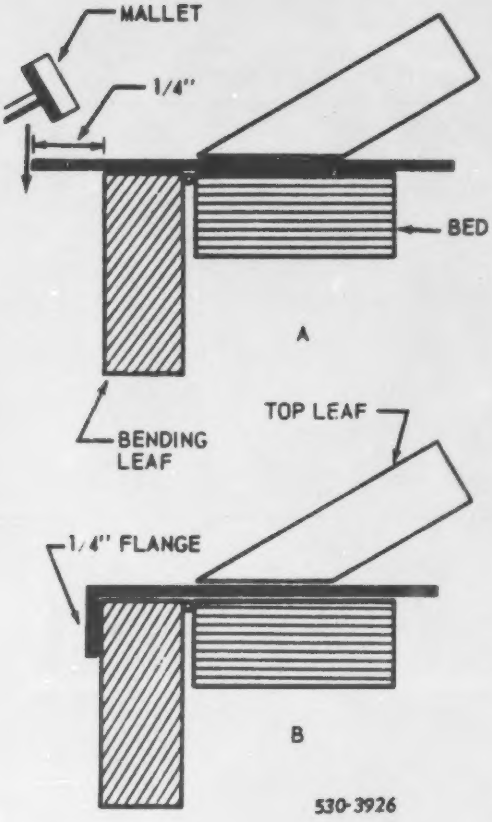


Figure 33. Bending ¼-inch flange with cornice brake.

rial is approximately 0.004 inch thicker than the gage shown on the chart. The recommendations shown on the chart are suitable for actual use; however, your work orders or job specifications may designate other instructions.

3-22. You can see by the chart in figure 28 that as duct width increases, it is necessary to increase the thickness (gage) of the metal, to use joint connections with additional strength, and to use appropriate bracing. For example, 26-gage galvanized iron (or 24-gage aluminum) sheet metal is adequate for ducts up to 12 inches wide if the metal is braced with cross brake bends. Notice that the type of joint connectors is determined by the length of the duct joints. If the joints are 35 inches or less in length, they may be connected with flat S-slips and drive slips. If the joints are longer than 35 inches (up to 7-foot 11-inch centers), they should be connected with standing seams or standing S-slips and drive slips.

3-23. **Tapped Connection.** A tapped connection, such as that shown in view A of figure 29, is used to join a takeoff fitting to a duct. A takeoff fitting (also called a takeoff or simply a fitting) is used to connect a smaller duct or branch line to a larger duct such as a trunk line. You may find some sheet metal workers using other names for the tapped connection of a takeoff, such as clinch lock, P-lock, or tap connector. In step 4, view D, of figure 29, you can see the flange (sometimes called a frame or collar) which forms a base for the takeoff fitting when installed in the trunk line opening. After insertion

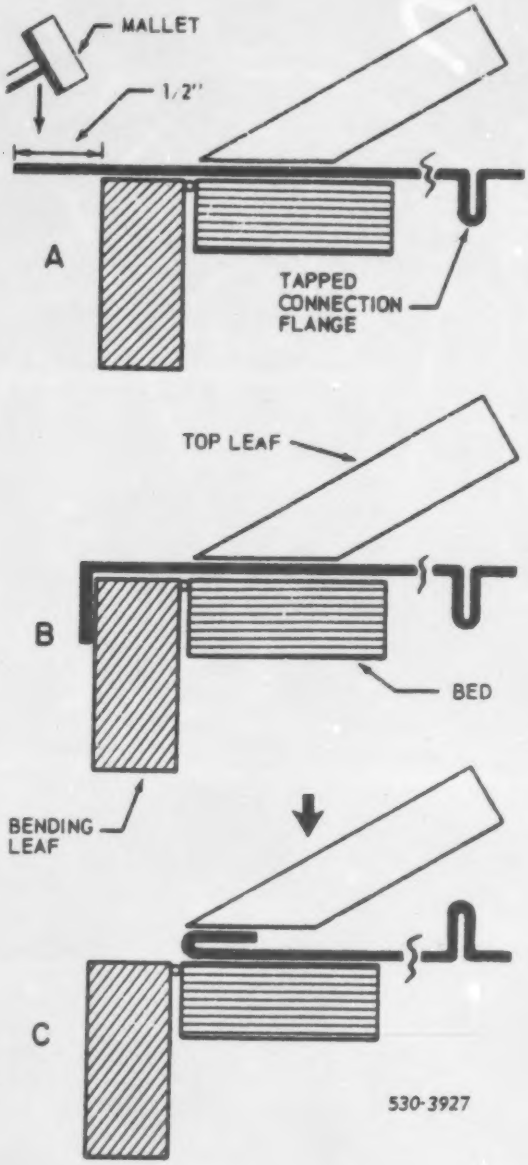


Figure 34. Using cornice brake to bend 180° fold for drive slip.

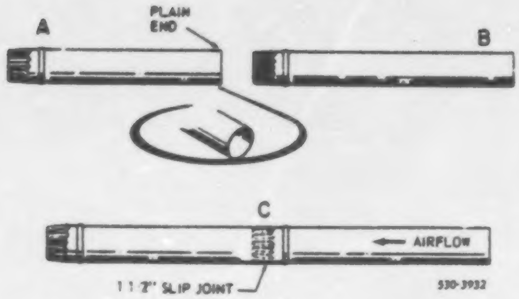


Figure 35. Joint connection for round duct.

in the opening, the tabs are bent 90° to lock the fitting to the trunk line. The shape of takeoff fittings may be curved, straight, or tapered; however, all make a flush fit with neat appearance.

3-24. The curved tapped connection illustrated in figure 29 is in the form of an elbow, and four pieces are required for its fabrication: two sides, a throat, and a heel. Pittsburg lock seams are used to join all four corners. The material allowance to make this tapped connection is included as each pattern is made. Note in view B and view C of the illustration that the allowance on each pattern is 1¾ inches.

3-25. Before the tapped connection is formed with a cornice brake, it is necessary to form the flanges and pockets for the Pittsburg lock seams. The ¼-inch flange is turned on the two side patterns, and the pocket is formed on the throat and heel patterns. Next, the ½-inch flange for the tapped connection is formed as shown in steps 1 through 4 of view D in figure 29. Bending this flange with a cornice brake is similar to the procedure used earlier in this chapter to form a standing seam (fig. 8).

3-26. After all four pieces have been formed and the elbow assembled, a hole is cut in the trunk line, the tapped connection inserted in the hole, and the tabs bent outward 90° with a hammer, or mallet, with a dolly or bucking bar used as a backing surface.

3-27. **Fabricating a Takeoff Fitting.** Fabrication is similar for all takeoff fittings and includes making seams, joint connectors, and tapped connections. We will explain making the pattern and allowances, notching, forming, and joining a tapered takeoff fitting such as that illustrated in figure 30. Notice that it will connect a branch line to the side of a trunk line, as shown in view A. View B is the elevation view of the right-hand side showing the length, rear height, front height, size of tapped connection flange, and the 1-inch straight (without taper). View C is the front elevation showing the width, rear height, and front height.

3-28. *Making a flat pattern.* From the information shown in figure 30, it is not difficult to develop the flat patterns shown in figure 31. You should remember from the sheet metal layout chapter in Volume 1 that the first step is to draw a plan view with the dimensions, as shown in figure 31. From the plan view, the pattern (stretchout) is developed by the parallel line method (except for the slanting sides). The pattern for the top and sides is in one piece because two Pittsburg lock seams are to be used to join the bottom piece. Flat pattern A is laid out by drawing a straight line (stretchout) equal to the perimeter of the top and two sides. Next, the two perpendicular element lines are drawn where the corners of the joint will be folded. The length of the upper stretchout line in view A is equal to the perimeter of the 12" x 6" opening of the transition. When the ends of the two stretchout lines are connected, the length of the slanting sides (true length) is determined. Flat pattern B for the bottom of the takeoff fitting is the same length as the slant length of the side which it will join.

3-29. *Making allowances.* After the flat patterns are laid out, the next step is to determine the seam allowances and additions, as shown in figure 32. This includes allowance for the S-and-drive slip connections, the Pittsburg lock seams, and the tapped connection. It doesn't make any difference which allowance is developed first. We have elected to first develop the allowances for the S-and-drive slips. This will require ½-inch allowance on both patterns. The allowance for the Pittsburg lock seams is made by allowing ¼ inch on each of the slant sides in pattern A (fig. 32) and 1 inch on two sides of pattern B. The allowance for the tapped connection is made on both patterns and includes ½ inch plus ½ inch for the flange and ¾ inch for the tabs. This makes a total of 1¾ inches allowed for the tapped connection.

3-30. *Notching.* After the allowances have been determined and marked, the notches and slits are cut, as indicated on patterns A and B of figure 32. The notches which form the ¾-inch tabs require two cuts and are spaced 1 inch apart in this example. However, in other patterns the length of each tab may be less or greater depending on the strength desired, on the size of the takeoff fitting, and on the effort required to reach and turn down the tabs after joining the fitting to a duct. Notice that each end of the S-and-drive connection allowances is notched with a 45° cut. The ends of the Pittsburg lock seam pocket allowance in pattern B are notched (cut) at 90° angles.

3-31. *Forming.* All of the bends indicated in figure 32 can be made with a cornice brake, mallet, and a Pittsburg lock forming machine. It is important to follow the proper sequence for making the bends so the top leaf of the cornice brake will not crush a fold already made. For example, cross brakes are always made first; however, the sequence of other bends may vary depending on the shape and direction of the bends. A general rule that will work in most cases for square or rectangular duct components is as follows: (1) cross brake, (2) bend side allowances according to the seam procedure, (3) bend end allowances according to the procedure for the type of joint, and (4) make the corner bends indicated on the pattern.

3-32. To make the bends for the takeoff fitting (fig. 32), the first step is to do the prescribed cross breaking. Pattern A (piece A) is placed in the cornice brake so that the metal is at a 45° angle to the top leaf, the metal is clamped with the top leaf, and the bending leaf is raised 10° to 15°. This procedure is repeated along the other cross brake lines.

3-33. Continuing with piece A only, the second step is to bend the ¼-inch flange 90° for the Pittsburg lock seam. This operation, as shown in figure 33, is performed with the cornice brake and mallet. This allows the ¼-inch flange to be bent without bending the end of the 1-inch straight and the end of the allowance for the drive slip connection. After bending 90° flanges at each side of piece A, it is necessary to straighten out each end for about 2 inches so that the metal can be clamped in the cornice brake to make the tapped connection bends.

3-34. The third step for piece A (fig. 32) is to make the bends which will be at the two ends of the takeoff fitting. The bends for the tapped connections are made with the cornice brake, as described in paragraph 3-25.

3-35. The 180° bends for the drive slip connection are made with the cornice brake, as illustrated in figure 34. The mallet is used because only the 1½-inch allowance for the two side pieces is to be folded 180°. (The ½-inch allowance for the S-slip connection on the top and bottom pieces must remain straight.) If desired, a hand seamer can be used to make the bend instead of the cornice brake and mallet. The ¼-inch 90° flange for the Pittsburg seam which was temporarily straightened for 2 inches on each end of piece A is now returned to the 90° angle with a hand seamer.

3-36. Step 4 of the forming process for piece A in figure 32 is to use the cornice brake to make the two 90° corner bends. The corner where the top side and the left side meet should be made first with the pattern positioned at the left end of the cornice brake. This will prevent the flange of the tapped connection from being damaged. Next, the 90° corner where the top side and the right side meet is bent in the same manner. This is the final step for piece A, which should now look like a finished takeoff except for the sloping bottom which is not yet in place.

3-37. The forming process for pattern B (piece B), which is the bottom of the takeoff (fig. 32), is accomplished in a similar sequence as for piece A. The first step is cross braking the pattern along the diagonal lines. The second step is to make the pocket side of the Pittsburg lock seams on the 1 inch allowed on each side of the bottom piece. This is done with a Pittsburg lock forming machine if available; if not, with a cornice brake as described in paragraph 2-23. The third step is to form the flange for the tapped connection end of the takeoff; then make a 25° bend downward along the straight allowance line which returns the bottom to the same plane as the duct branch. When making this 25° bend, it is important *not* to use excessive clamping pressure with the top leaf of the cornice brake. Excessive pressure would damage the Pittsburg seams. The fourth step is not necessary for the bottom piece of this component.

3-38. *Assembly and joining.* The takeoff fitting which we have discussed in the preceding paragraphs is easy to assemble. Piece A (fig. 32) is placed so that it rests on the top side, the bottom piece (B) installed so that ¼-inch flanges of the two sides fit into the pockets of the Pittsburg seam, and the locking edges of the Pittsburg seam are folded over. This completes the assembly; now the takeoff fitting can be joined to the hole in the trunk line by inserting the tabs into the hole until the flange rests against the edges of the hole, and the tabs are bent 90° outward to make a tight connection. To join the branch duct to the takeoff fitting, S-and-drive slips are used.

3-39. **Joint Connections For Round Ducts.** Joint connections for round ducts are somewhat different from those for rectangluar ducts. Figure 35 shows a 1½-inch slip joint. One end of each piece of pipe is crimped with a crimping machine, as you learned in Volume 2. A bead made with a beading machine will strengthen the duct and help align the joints during installation. This connection is sometimes called a slip joint and is assembled when the crimped end is slipped into the plain end of another joint until the bead is flush with the plain end. The slip joint is fastened together with sheet metal screws or rivets. It is important that the airflow be in the direction indicated in view C.

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Airflow Control Devices Used in Heating, Air-Conditioning, and Ventilating Duct Systems

THIS CHAPTER CONCERNS airflow through duct systems. You will find that air, like water, passes easily through straight ducts, but at turns (elbows) the flow becomes turbulent, forms eddies and whirlpools, and moves against the main current. To minimize turbulence and resistance to airflow, you must understand the characteristics of airflow through duct systems. For example, you must know what size and shape of elbow permits the best airflow. You must also know how splitters and turn vanes can be used to improve airflow, as well as how dampers can restrict airflow and deflectors can direct airflow. This chapter will help you to understand the characteristics of airflow through duct systems, how to determine dimensions of duct system components, and how duct system components are fabricated and installed.

4. Characteristics and Control of Airflow Through Duct Systems

4-1. Working drawings and blueprints should specify how new systems are to be fabricated to provide maximum flow of air; however, you need to understand and know how to apply principles of good airflow as you fabricate and install ducts that carry air from heating, ventilating, or air-conditioning units to different parts of buildings. In Volume 1 we illustrated some of the symbols used on working drawings for ducts, dampers, registers, grilles, and louvers. Right now is a good time to review these illustrations and refresh your memory.

4-2. **Airflow.** Forced air systems for heating, ventilation, and air conditioning include motor-driven blowers; coils, filters, and associated components of the heating and cooling units; the supply duct system; and the return duct system. When an engineer designs a forced air system for a building, he considers many factors. For example, after he determines the heating and cooling load requirements, he must design a duct distribution system that will carry the required flow of air with the least amount of resistance. Some of the factors he considers are static pressure, velocity pressure, friction loss, and dynamic losses. Only some of these factors are directly related to your job of fabricating and installing duct systems; therefore, for instructional purposes we will use the term "pressure loss" to describe the conditions which are affected by the quality of your work.

4-3. As with water, air flowing through a duct system loses some pressure because of friction with the sides of the duct and because of turbulence resulting from changes in direction of the duct or changes in the cross-sectional area of the duct. In figure 36 you can see examples of turbulence in duct system components as the flow of air tends to whirl and move in different directions. There is less pressure loss in the straight duct with uniform cross section than in the other examples which involve a change in direction or a change in cross-section area.

4-4. Some of the general rules that apply to air distribution systems are as follows:

- Select the proper size of duct.
- Pipe the air as directly as possible to the required location.
- Avoid sharp turns.
- When the size of or shape of a duct must be altered, make the change as slight as possible.
- Avoid restrictions of flow in elbows and transformation pieces.
- Make rectangular ducts as nearly square as possible.
- Reduce the friction by using smooth duct materials.

4-5. **Straight Duct.** Air being forced through a straight duct encounters less pressure loss than through elbows or transitions. The loss through a straight duct is primarily caused by friction as

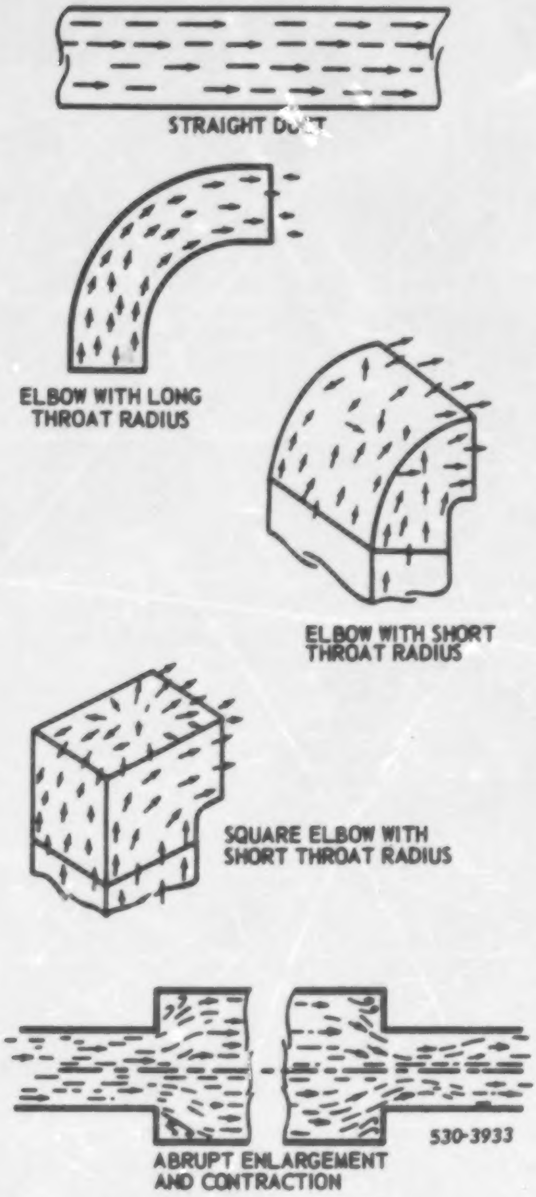

STRAIGHT DUCT
ELBOW WITH LONG THROAT RADIUS
ELBOW WITH SHORT THROAT RADIUS
SQUARE ELBOW WITH SHORT THROAT RADIUS
530-3933
ABRUPT ENLARGEMENT AND CONTRACTION

Figure 36. Air turbulence in duct components.

the air touches the sides of the duct; the loss increases when the inside of the duct is rough, when the length of the duct is increased, or when a smaller duct is used. The pressure loss is less through a round duct than through a square or rectangular duct; however, the square duct is better than the rectangular duct.

4-6. When you are fabricating straight duct, the size, shape, and length are usually specified in the working drawings, therefore your main consideration will be to make the joint connections and seams as smooth as possible to reduce friction to a minimum.

4-7. **Diverging and Converging Duct.** It is sometimes necessary to enlarge a straight duct, as shown in figure 37, to install a cooling or heating coil. Coils like this are often larger than the duct and make it necessary to install two transitions. In the illustration, angle A is in the diverging transition, and angle B is in the converging transition. In both transitions it is important to make the changes as gradual as possible. In a diverging transition, angle A should not exceed 20°; splitters should be installed to reduce pressure loss and to insure even distribution of the air through the coil. A converging transition usually does not require splitters; however, angle B should not exceed 60°. (We will further discuss splitters in paragraphs 5-2 through 5-5.)

4-8. **Elbows.** Elbows used in duct systems cause air turbulence and pressure loss which can be minimized by proper design and fabrication of the elbows. It is important to avoid sharp turns by using elbows with larger throat radiuses and duct dimensions that allow maximum airflow.

4-9. Elbows in square or rectangular ducts have a dimensioning characteristic that must be understood and utilized if maximum airflow is desired. This characteristic concerns the width of the elbow, which is somewhat different from the width of straight duct sections. Figure 38 illustrates two elbows in a rectangular duct. Notice that the width of elbow A is 12 inches, and the width of elbow B is 6 inches. *The width of an elbow in a square or rectangular duct is always the dimension which lies in the same plane as the radius of the elbow.*

4-10. Elbow A in figure 38 has more turbulence and resulting pressure loss than elbow B because of the ratio between the throat radius (R) and the elbow width (W). It is desirable to have a ratio of between 1 to 1 and 2 to 1, the latter ratio being the more desirable. The throat radius ratio is also called *inside radius ratio* and is determined by dividing throat radius (R) by width (W). For example, the inside radius ratio for elbow A is 1 to 1, as determined by substituting the width and throat radius dimensions ($\frac{R}{W} = \frac{12}{12} = \frac{1}{1} = 1$). When speaking of ratios, it is common practice to use the equivalent value such as 1 = 1. Thus, a ratio of 2 to 1 may be called a ratio of 2, and a ratio of 1 to 2 may be called a ratio of 0.5, etc.

4-11. Elbow B in figure 38 has an inside radius ratio of 2, or $\frac{R}{W} = \frac{12}{6} = \frac{2}{1} = 2$, which is more desirable than a ratio of 1. Both

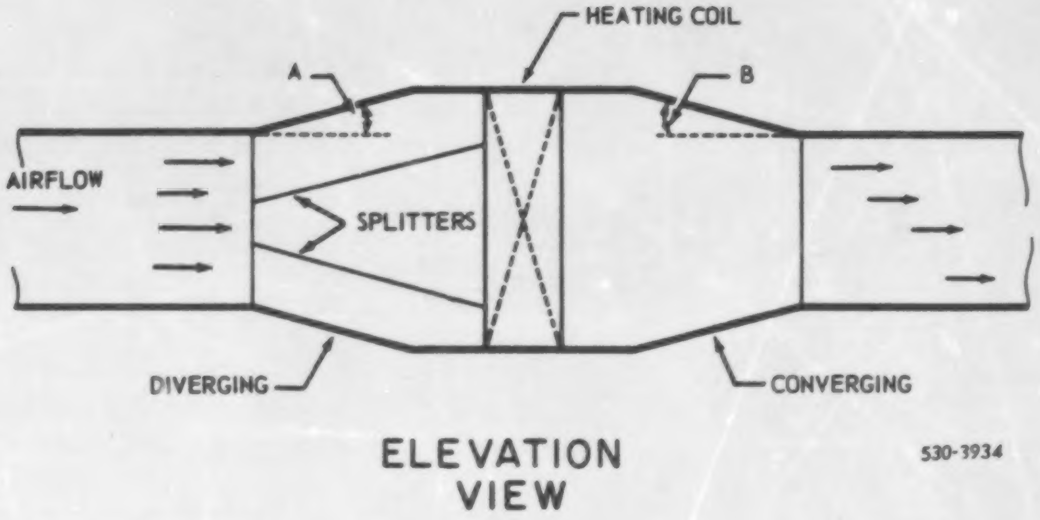

HEATING COIL
A
B
AIRFLOW
SPLITTERS
DIVERGING
CONVERGING
ELEVATION VIEW
530-3934

Figure 37. Diverging and converging ducts.

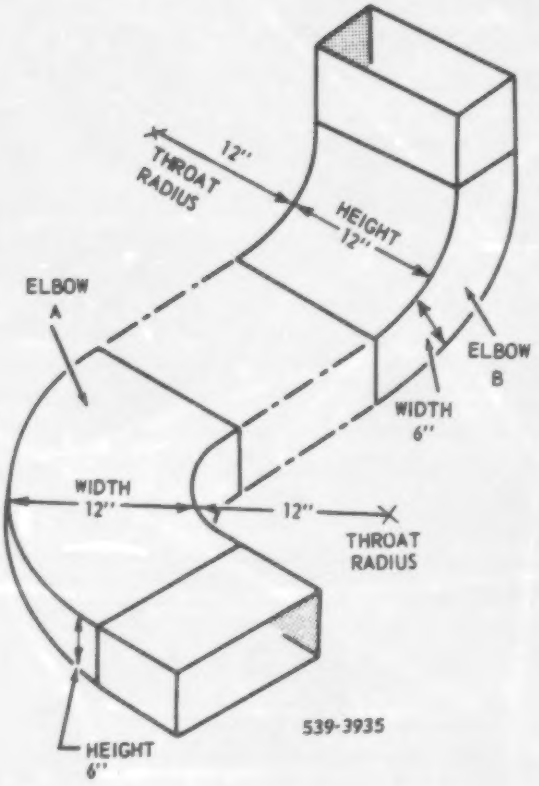

12"
THROAT RADIUS
HEIGHT 12"
ELBOW A
ELBOW B
WIDTH 6"
WIDTH 12"
12"
THROAT RADIUS
HEIGHT 6"
539-3935

Figure 38. Rectangular duct elbows.

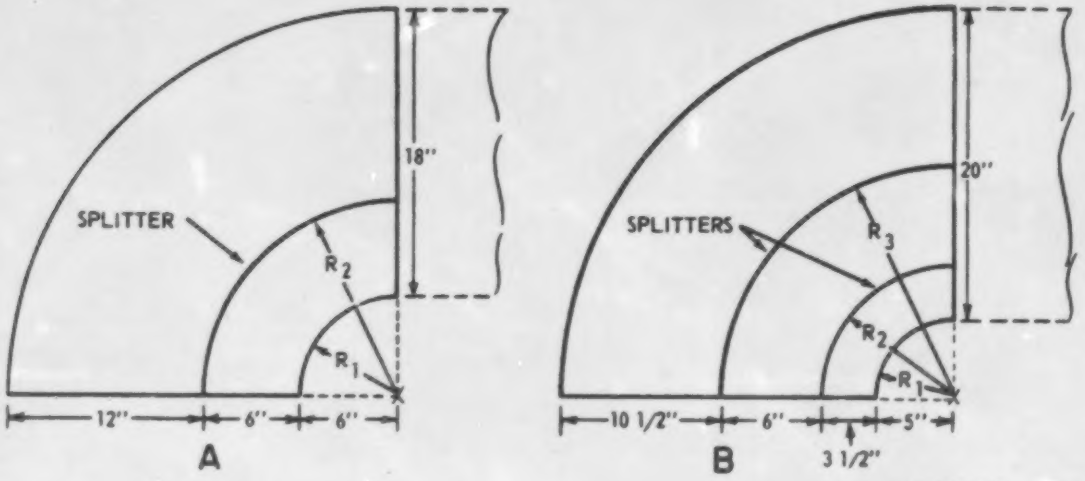
elbows in the illustration have satisfactory airflow, although elbow B has the better.

5. Duct System Components for Control of Airflow

5-1. Several devices are used inside duct systems to control airflow, such as splitters and turn vanes which are used to prevent turbulence as the air flows around turns inside of square or rectangular ducts. Devices such as volume dampers are installed inside duct systems to reduce or shut off airflow. Devices such as diffusers and registers are used at supply outlets to control the volume and direct the airflow in desired directions.

5-2. **Splitters.** Splitters, such as those shown in figure 39, are used to improve the flow of air through elbows that do not have a desirable inside radius ratio. Splitters reduce the turbulence of the airflow as it passes through an elbow by dividing the flow of air into passages that have better inside radius ratio. Splitters are also used when the outlet end of an elbow does not connect to another duct of the same size and the air is discharged into a large space or into the atmosphere.

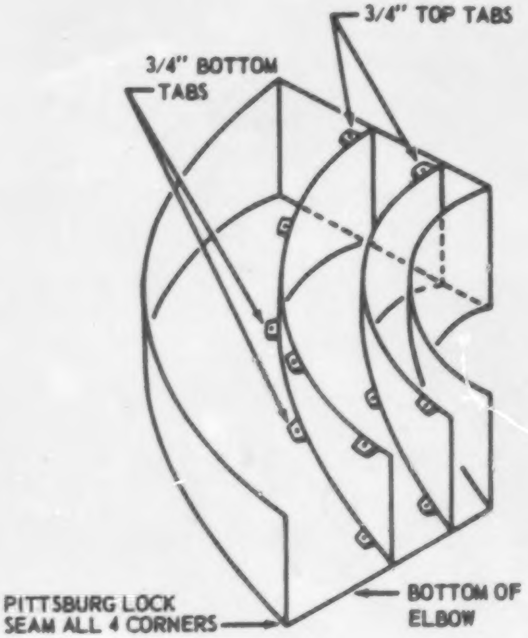
5-3. Elbow A in figure 39 if used without a splitter will have an inside radius ratio of 0.33, or $\frac{R_1}{W} = \frac{6}{18} = \frac{1}{3} = 0.33$, which will result in excessive turbulence of the air passing through the elbow. Notice in the illustration that the splitter is not through the center of the elbow but divides it into one 6-inch passage and one 12-inch passage. The inside radius ratio for the 6-inch pas-



530-3936

Figure 39. Splitters in rectangular duct elbows.

sage is 1, or $\frac{R_1}{W} = \frac{6}{6} = \frac{1}{1} = 1$. The inside radius ratio for the 12-inch passage is also 1, or $\frac{R_2}{W} = \frac{12}{12} = \frac{1}{1} = 1$. Thus, by the use of a splitter placed in the proper location, we have reduced the turbulence and pressure loss through the elbow.



530-3937

Figure 40. Installing splitters.

5-4. Elbow B in figure 39 if used without splitters will have an inside radius ratio of 0.25, or $\frac{R}{W} = \frac{5}{20} = \frac{1}{4} = 0.25$, which will cause excessive turbulence and pressure loss. When two splitters are installed as shown in the illustration, each passage will have inside radius ratios that permit air to flow with a minimum of turbulence and pressure loss.

5-5. Figure 40 shows how splitters are installed during the fabrication of elbows for square or rectangular ducts. You can see that it would be difficult to install the splitters after an elbow is assembled. Notice how tabs on the splitters permit fastening with rivets or spot welds. After the splitters have been fastened to the bottom of the elbow, the top is attached with Pittsburg lock seams. The last step is to fasten the splitters to the top. Remember that allowances (¾ inch in this example) must be made on the pattern of each splitter before it is cut to size.

5-6. **Turn Vanes.** Turn vanes, such as those shown in figure 41, are used in elbows of square or rectangular ducts to reduce turbulence and pressure loss and to provide a more uniform distribution of air. Turn vanes are especially valuable in elbows connected to supply registers or grilles.

5-7. In figure 41 you can see that the turn vanes form several small elbows which function very much like splitters. However, the number of turn vanes and their distances apart are determined differently from those for splitters. For best airflow, the turn vanes should be spaced so that they will have an *aspect ratio* of 5 (5 to 1). *The aspect ratio of an elbow is equal to the height*

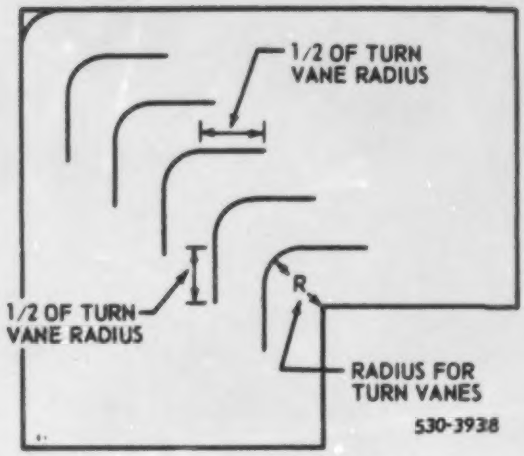


Figure 41. Turn vanes in square elbow.

of the elbow divided by its width ($\frac{H}{W}$). (Remember that the width of an elbow is in the same plane as its radius.) For example, if the elbow in figure 41 is 15 inches high, we can substitute 15 for H, solve for W (width or radius of turn vanes), and find that the turn vane width should be 3 inches if maximum airflow is to be obtained. Therefore, the turn vanes should be installed 3 inches apart to effectively divide the elbow into several smaller elbows, each having the desired aspect ratio of 5.

$$\frac{H}{W} = 5$$

$$\frac{15}{W} = 5$$

$$W = \frac{15}{5}$$

$$W = 3$$

5-8. To determine how many turn vanes are needed, the distance from the throat corner to the heel corner of the elbow is measured and then divided by the 3-inch radius. For example, if in figure 41 the distance from throat to heel is 24 inches and each turn vane is to be 3 inches apart, you should divide 24 by 3 to find that eight turn vanes are needed.

5-9. Notice in figure 41 that each turn vane is straight on both sides of the 90° radius bend. The length of each straight edge is equal to ½ the distance (radius) between the turn vanes. Since in this example we determined the turn vanes to be 3 inches apart, each straight edge should extend 1½ inches past the 90° radius bend.

5-10. Turn vanes are installed with tabs and rivets (or spot welds) in a manner similar to that for splitters. Figure 41 does not show the tabs, but each end of each turn vane should have at least three tabs, one in the middle of the bend and one on each straight edge.

5-11. **Volume Dampers.** A damper is a movable blade used to vary the volume of air flowing through a duct system. Some dampers make only minor changes in volume, some completely shut off airflow, and others permit a range of airflow adjustment from maximum to zero. Types of volume dampers discussed in this chapter include deflecting dampers, butterfly dampers, and louver dampers.

5-12. *Deflecting damper.* A deflecting damper, such as that shown in figure 42, is sometimes called a *splitter damper.* It consists of a single blade hinged at one edge, and the blade can be positioned with an accessible control handle. This directional control for airflow is installed on the outside of the duct so that the damper can be positioned after the duct system has been assembled and installed. In the illustration you can see how airflow can be increased or decreased in the branches by changing the position of the deflecting damper. Deflecting dampers are usually positioned (set) during the first operational checkout of the airflow system; and after a balanced airflow is achieved, the damper is locked in position with a wingnut.

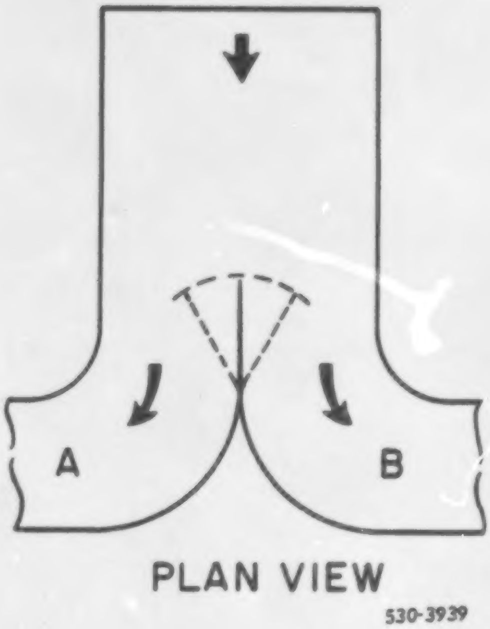


Figure 42. Deflecting damper in a duct system.

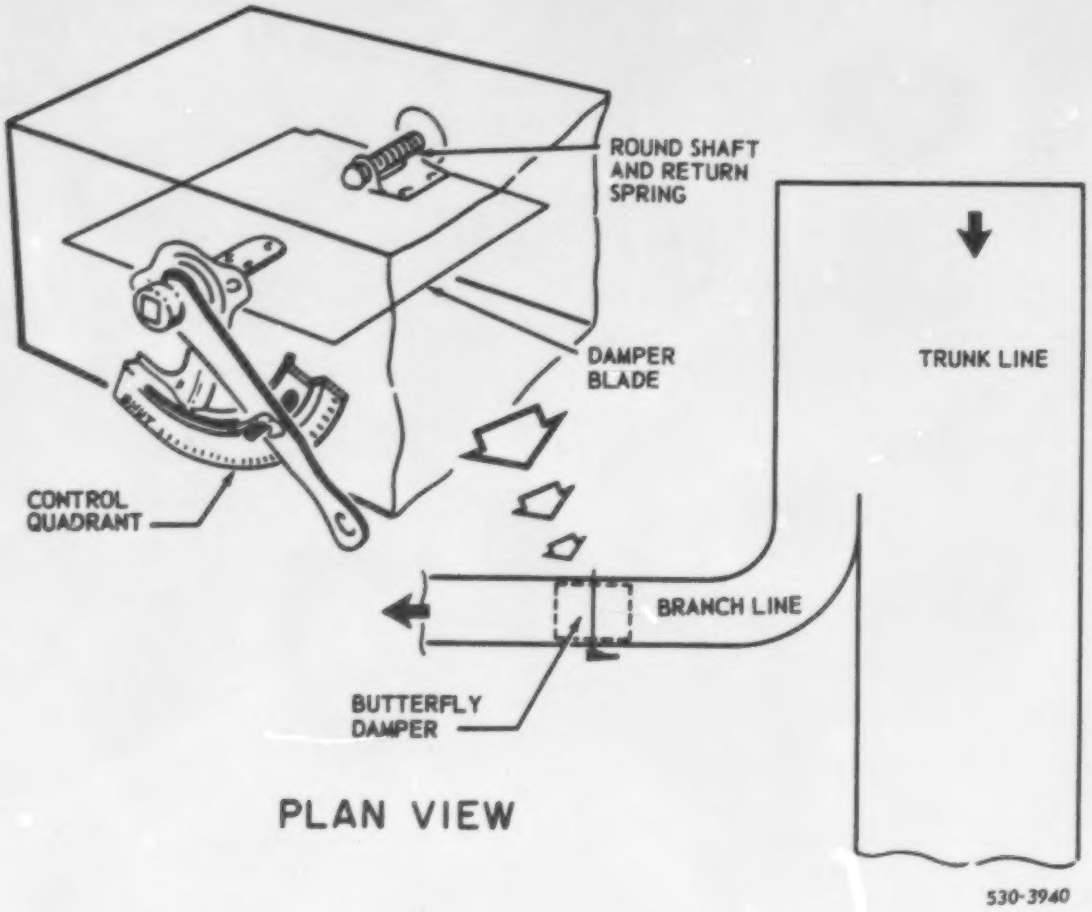


Figure 43. Butterfly damper in a branch line.

5-13. Deflecting damper blades are usually made from material 2 gages heavier than the duct and are attached to shop-made shafts and handles or attached to factory-made directional control quadrants. The damper blade length is the same as the height of the duct less a clearance of approximately ¼ inch. The width of the blade will vary according to the amount of airflow to be deflected. Usually, the width of deflecting dampers is approximately ¾ the width of the branch line, as shown in figure 42.

5-14. *Butterfly damper.* A volume control damper like that shown in figure 43 is commonly called a butterfly damper. It has a blade made from sheet metal, is hinged in the middle, and is usually located in the middle of a straight duct. With this damper, airflow can be adjusted from zero to full flow by positioning the angle of the blade with the handle of the control quadrant. Notice in the illustration that the butterfly damper is located near the branch takeoff. It should *not* be located near the outlet of the branch duct because, if partly closed, it creates two high-velocity airstreams along the duct instead of a uniform flow. Also, the angle of the damper blade will cause the air to flow from the duct at an undesirable angle.

5-15. The blade of a butterfly damper is usually made of sheet metal, which is 2 gages heavier than the duct. The size of the blade is the same as the inside dimensions of the duct, except for a clearance of ¼ inch. If a tight fit is desired, a strip of felt can be installed around the edges of the blade.

5-16. In figure 43 you can see how a butterfly damper is installed in a branch line. Now look at figure 44 and see the various pieces of hardware which are used with a butterfly damper. Notice that the control quadrant, which has a removable handle, is riveted to the outside of the duct and is the pivot for the square shaft, which is riveted to the damper blade. At the

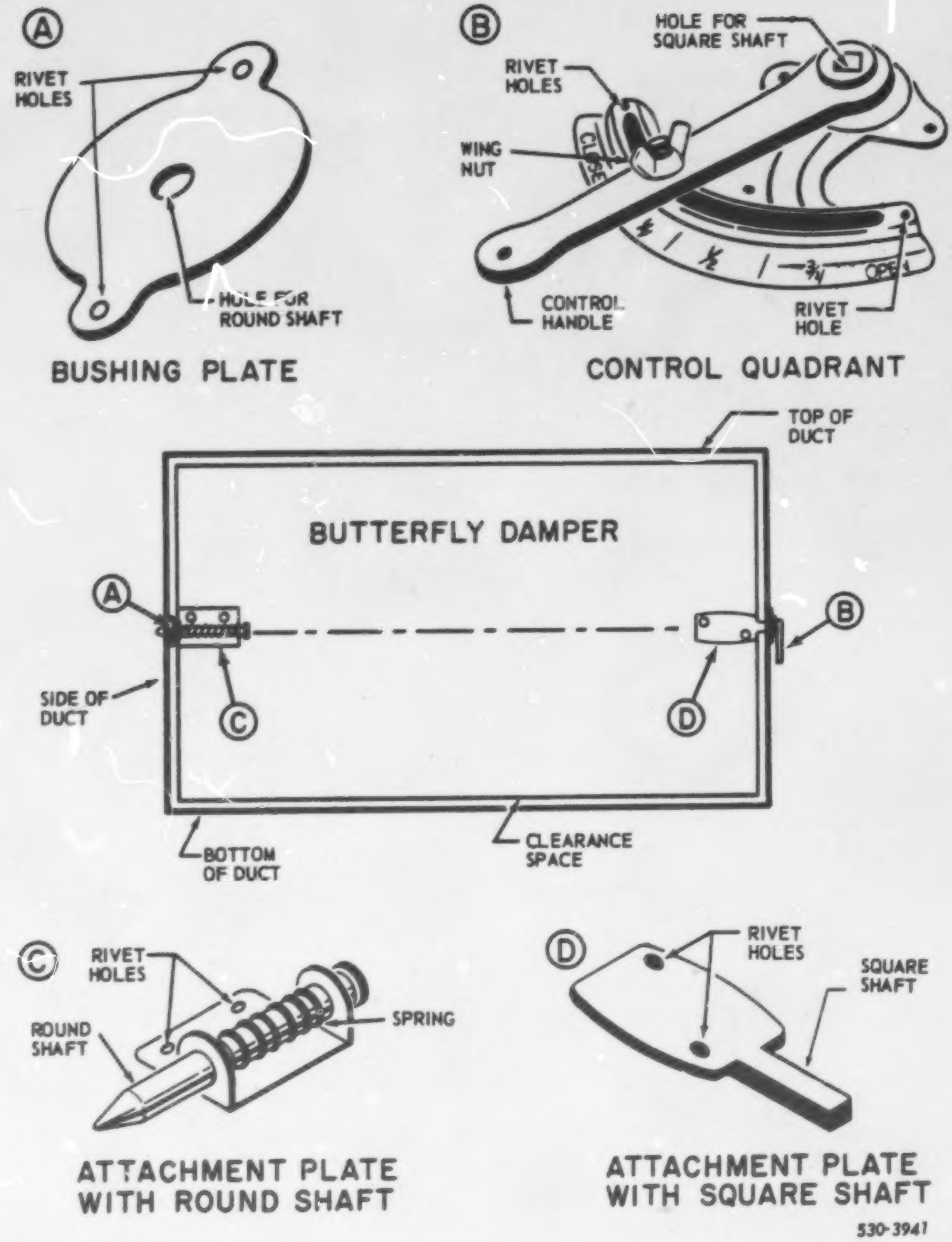

Ⓐ
RIVET HOLES
HOLE FOR ROUND SHAFT
BUSHING PLATE
Ⓑ
HOLE FOR SQUARE SHAFT
RIVET HOLES
WING NUT
CLOSE
1/4
1/2
3/4
OPEN
CONTROL HANDLE
RIVET HOLE
CONTROL QUADRANT
TOP OF DUCT
BUTTERFLY DAMPER
Ⓐ
Ⓑ
SIDE OF DUCT
Ⓒ
Ⓓ
BOTTOM OF DUCT
CLEARANCE SPACE
Ⓒ
RIVET HOLES
ROUND SHAFT
SPRING
ATTACHMENT PLATE WITH ROUND SHAFT
Ⓓ
RIVET HOLES
SQUARE SHAFT
ATTACHMENT PLATE WITH SQUARE SHAFT
530-3941

Figure 44. Butterfly damper components.

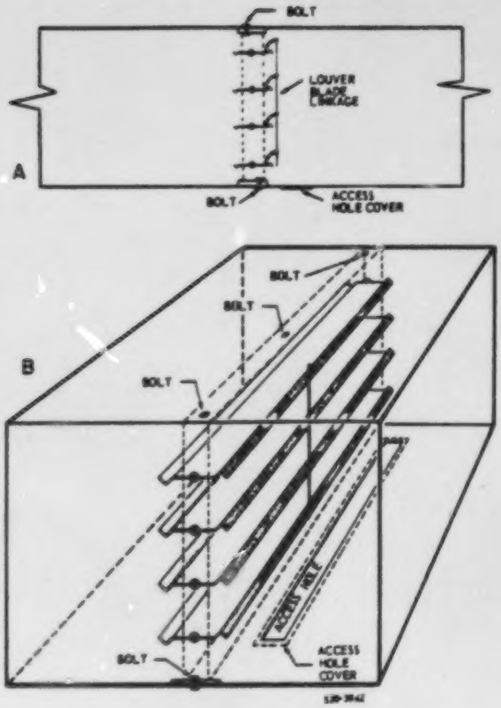


Figure 45. Louver damper.

other end of the centerline, the round shaft attachment plate is riveted to the blade. Notice that the round shaft bushing plate is riveted to the inside of the duct.

5-17. Before the bushing plate and control quadrant are riveted to the duct, holes must be drilled so that the two shafts can extend through the duct. To install the assembled butterfly damper in a duct, the blade is positioned inside the duct and the square shaft is inserted into the square hole of the quadrant. The round shaft is spring loaded and will retract enough to allow the round shaft to be inserted into the bushing plate with the round hole. Next, the control handle is installed in the square shaft extending through the control quadrant. The wingnut can be tightened to lock the handle and damper blade at the desired angle.

5-18. *Louver dampers.* Many designs have been developed which use a series of adjustable louvers inside of ducts or at the outlets. On some working drawings this type of volume damper is labeled as a multiblade damper, whereas on other drawings the same damper may be labeled as a louver damper. Figure 45 shows a louver damper which is used to reduce or shut off the flow of air through a duct. Each of the four damper blades illustrated pivots on its centerline axis when the connecting linkage is moved. Although not illustrated, the linkage can be operated by various means, such as motors, springs, weights, and airflow, or can be manually positioned with gears or quadrant handles. Notice in figure 45 how the edges of each blade have V-grooves so that when tilted to vertical position, the grooves fit together to make a better seal. These grooves also act as stiffeners for each blade and reduce vibration as air flows between the blades.

5-19. Louver dampers are usually purchased as factory-made assemblies, and your job will be to install them correctly. The louver damper shown in figure 45 is attached to the inside of the straight duct with bolts before the duct is installed and the louver blade linkage connected to its actuating device. Notice that an access hole and cover plate are made so that inspection or maintenance can be performed when necessary. During installation it is important to use boltheads that do not interfere with movement of the blades.

5-20. Figure 46 shows an automatic louver damper used as a fire damper at exhaust outlets or in a duct that passes through a firewall. This type of damper is set, at time of installation, to permit full airflow. However, if a fire occurs, the fusible link melts and allows the spring-loaded damper blades to close. This shuts off the airflow and prevents a draft that could intensify the fire. Installation of an automatic louver fire damper is similar to installation of other louver damper assemblies.

5-21. Figure 47 shows another variation of a louver damper where the blades are normally closed but will automatically open when the exhaust fan is in operation. The exhaust system illustrated is for ceiling installation; however, similar units are available for wall installation. When you are installing or replacing this kind of louver damper, be sure the correct type is used so that the blades will be fully closed when the fan is not operating and the wind will not pass through the damper in the wrong direction.

5-22. **Ceiling Diffusers.** Several types of ceiling diffusers are used at the supply outlet of duct systems. Figure 48 shows a round diffuser with an adjustable damper assembly. Pictorial view C shows the diffuser as it will appear when installed over the damper assembly (B). View D is a cutaway view of the diffuser showing how the turn vanes diffuse the airflow. Notice how the airflow is dispersed in all directions from the diffuser. View B shows the parts of the volume damper assembly, including the frame (ring), adjustable (butterfly) damper blades, and control knob. The blades are opened or closed by

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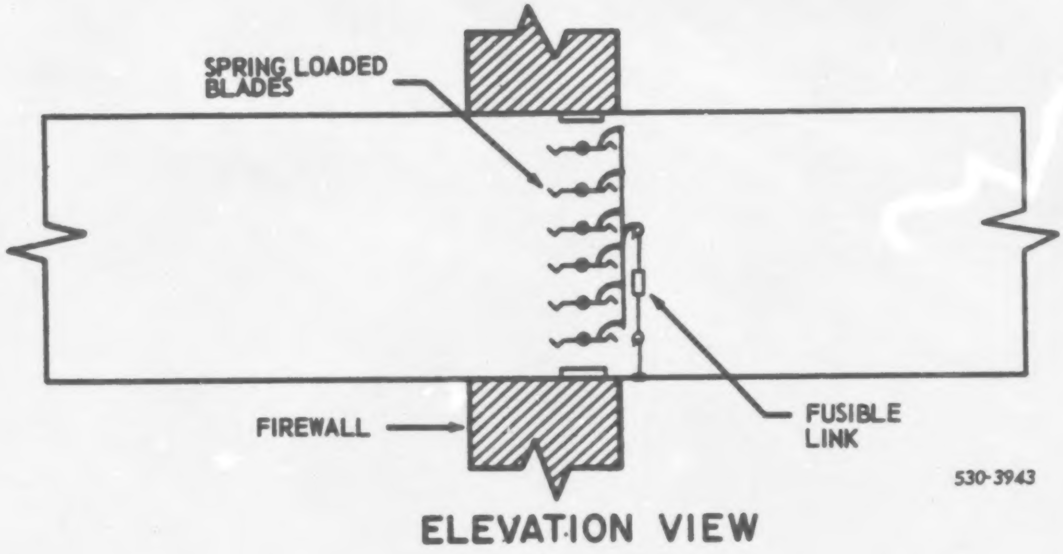
SPRING LOADED BLADES
FIREWALL
FUSIBLE LINK
530-3943
ELEVATION VIEW

Figure 46. Automatic louver fire damper.

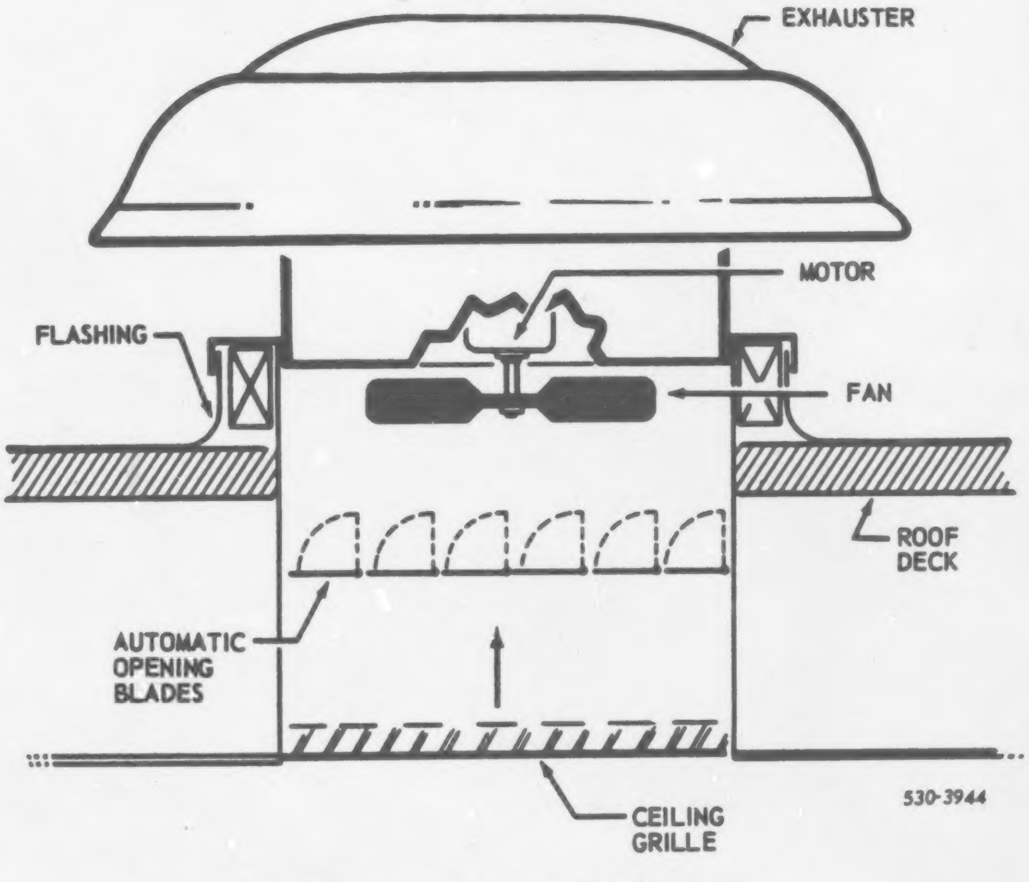
EXHAUSTER
MOTOR
FLASHING
FAN
ROOF DECK
AUTOMATIC OPENING BLADES
CEILING GRILLE
530-3944

Figure 47. Louver damper used in exhaust system.

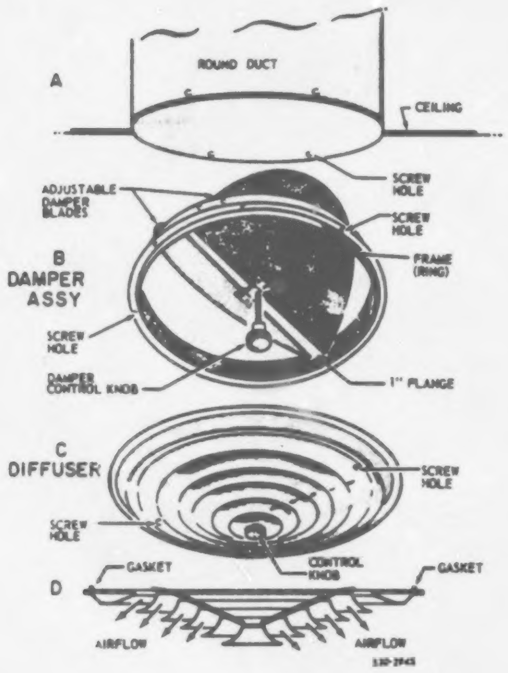
ROUND DUCT
A
CEILING
SCREW HOLE
ADJUSTABLE DAMPER BLADES
SCREW HOLE
FRAME (RING)
B
DAMPER ASSY
SCREW HOLE
DAMPER CONTROL KNOB
1" FLANGE
C
DIFFUSER
SCREW HOLE
SCREW HOLE
GASKET
CONTROL KNOB
GASKET
D
AIRFLOW
AIRFLOW
530-3945

Figure 48. Ceiling diffuser and volume damper.

turning the knob which is attached to a threaded shaft. Some damper assemblies of similar design have a pull chain which opens or closes the blades.

5-23. The frame of the damper assembly, shown in view B, has a 1-inch flange that fits into the supply duct (A), and four sheet metal screws secure the flange to the inside of the duct. The duct has been previously secured with hangers so that its edges are flush with the ceiling; therefore, when the damper assembly is inserted and secured with screws, the damper frame will fit snug against the ceiling. Next, the diffuser is attached to the damper with four sheet metal screws. Notice in view D that the diffuser has a circular gasket that prevents air from leaking and causing smudging (streaks of dust or dirt around diffusers). The ceiling diffuser and volume damper, shown in figure 48, are also available to fit square supply duct outlets, the main difference being a square-shaped damper assembly and a square-shaped diffuser.

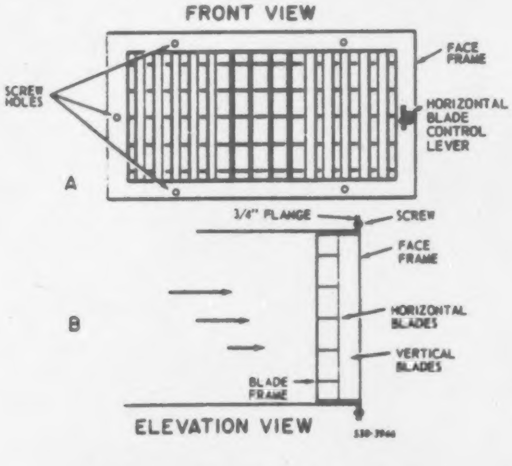
FRONT VIEW
SCREW HOLES
FACE FRAME
HORIZONTAL BLADE CONTROL LEVER
A
3/4" FLANGE
SCREW
FACE FRAME
B
HORIZONTAL BLADES
VERTICAL BLADES
BLADE FRAME
ELEVATION VIEW
530-3946

Figure 49. Multiple blade register.

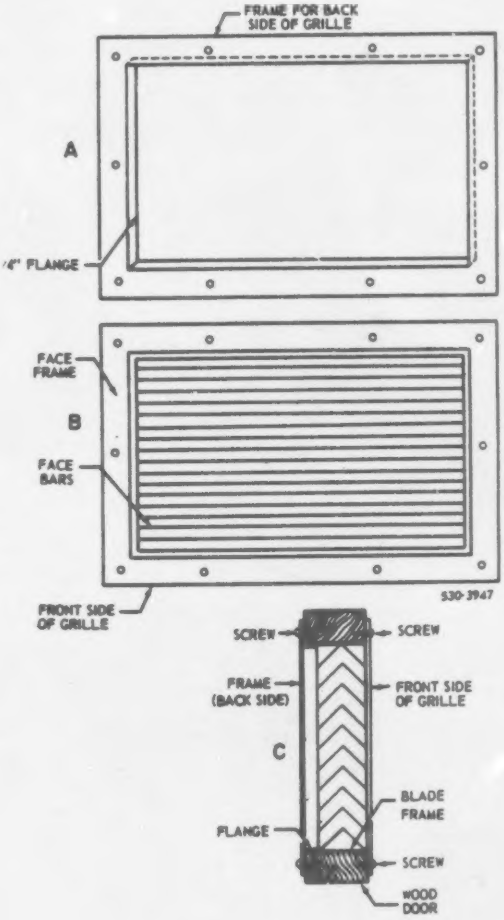
FRAME FOR BACK SIDE OF GRILLE
A
1/4" FLANGE
FACE FRAME
B
FACE BARS
FRONT SIDE OF GRILLE
530-3947
SCREW
SCREW
FRAME (BACK SIDE)
FRONT SIDE OF GRILLE
C
BLADE FRAME
FLANGE
SCREW
WOOD DOOR

Figure 50. Door return grille.

5-24. **Registers.** Several types of registers are used at the supply outlets of ducts to control volume and direction of the airflow. The register shown in figure 49 is a multiple-blade register with two sets of blades. The horizontal row of blades is connected with linkage that is controlled by the hand-operated lever on the right side of

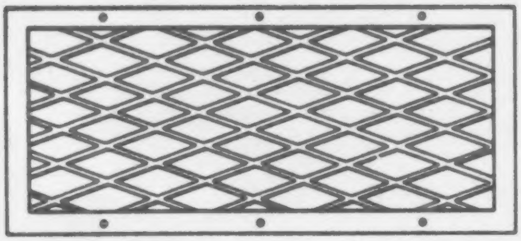

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Figure 51. Perforated metal grille.

the face frame. The horizontal blades can be adjusted from full-flow position to full-closed position. The horizontal blades operate somewhat like the louver damper blades in figure 45, although the pivot axis is usually at the back side of each blade instead of at the center. During adjustment of the horizontal blades from full-open to the closed position, the front edge of the blades will lower through a 90° arc.

5-25. The vertical blades shown in figure 49 are not linked together but are set individually to the desired angle of deflection. The vertical blades may be adjusted with your fingers or with a small wrench that fits one blade at a time. For a register to give maximum control of airflow, the air coming through the duct must be evenly distributed over the entire area of the register. If the register is located close to an elbow, turn vanes are usually used to insure even distribution of the airflow.

5-26. View B in figure 49 shows a side view and how the blade frame is attached with sheet metal screws to a ¾-inch flange turned 90° at the end of the rectangular duct. The blade frames should have approximately ¼-inch clearance when installed in a duct.

5-27. **Grilles.** Several types of grilles may be used where directional airflow is not important. Grilles do not have adjustable blades or louvers; they are used to cover the return air openings of ducts or are installed in doors or walls for ventilation purposes. Figure 50 shows a grille installed in a door. The blades in this type of grille allow air to pass but limit sound and sight. Grilles are usually factory made; however, some of the simple designs can be shop made. View B in figure 50 is the front side of the grille and shows the face frame and face bars; view C is a side view showing the shape of the blades, which are held in place by the blade frame. Notice that the blade frame is inserted into a cutout made in a door and held in place with screws. As with registers, the hole is cut to allow ¼-inch clearance when the grille is installed. The frame shown in view A is for the back side of the grille, has a ¼-inch flange, and is held in place with screws.

5-28. Not all grilles use blades or louvers. Sometimes perforated metal grilles are used to cover ventilation or return air openings in doors or walls. Perforated grilles have various ornamental patterns such as squares, diamonds, and circular shapes. The perforated metal grille shown in figure 51 has a diamond pattern.

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CHAPTER 3

Fabrication, Installation, and Repair of Sheet Metal Heating, Air-Conditioning, and Ventilating Duct Systems

THIS IS THE turning point in your career development course because now you are ready to "put together" the many bits of information which you have already learned. In this chapter, as well as the remaining chapters of the volume, you will use the bits of information as you learn how a complete duct system is fabricated, installed, and repaired.

2. This chapter concerns a complete duct job from the initial planning through the fabrication and installation as well as the repair of various component parts. The discussions are based on the working drawings in foldouts 1 and 2 (located at the back of the text), which show the duct system of a readiness crew building. These working drawings have been used because this duct system is typical of other duct systems you will encounter. You will recall previously learned information as you plan, lay out, fabricate, and install components of the duct system. For example, in the planning stages you will determine the types of seams, joints, and bracing to use. You will also select the proper materials, including sheet metal, registers, grilles, diffusers, louvers, dampers, and insulation. Next, you will lay out the patterns (with allowances) and accomplish the cutting, notching, forming, and assembly. This is followed by hanging, aligning, and insulating the duct sections and installing the registers, grilles, and diffusers. Last in the chapter are the repair jobs that may occur in the system.

3. It is appropriate to begin with a duct system that distributes air through a building because as a sheet metal worker you will spend much of your time working with duct systems similar to the one described here.

6. Planning a Duct System

6-1. Now that you know what ducts are for and what parts make up a duct system, let's go through the complete process of fabricating and installing a duct system. This section concerns the preliminary planning and selection of materials and components to be used. Normally, AF Form 1445, Materials and Equipment List, will include the materials and components for a new job; however, for repair jobs you will do the selecting. Therefore, for training purposes this section includes how the materials and components shown on the working drawing are selected. You need to know how the materials and components are selected so that you can identify items listed on AF Form 1445 and recognize where and how they are to be used. For example, when you pick up several sheets of metal at the material holding area, you must know where each sheet is to be used and how it is to be cut without waste.

6-2. **Preliminary Planning.** The working drawings shown on foldouts 1 and 2 (located at back of volume) do not specify the types of seams, joints, or bracing to be used; therefore, you must study and analyze the drawings to determine how the system is to be fabricated and installed.

6-3. *System breakdown.* The first step of preliminary planning is to break down the system into subsystems, sections, and joints. Refer to foldout 1 as we describe how the system is broken down into trunk lines A, B, and C.

6-4. The supply duct system begins at the heater room in the middle of the working drawing (FO 1). Notice that trunk line A is a 24" x 14" duct that connects the supply plenum of the heating and cooling units to the trunk lines that branch to the right and left wings of the building. Trunk line B supplies the right wing, and trunk line C supplies the left wing. The length of these three trunk lines can be determined by measuring with an architect's scale or a conventional rule and converting to feet in accordance with the scale shown on the drawing.

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6-5. Trunk line A is a 24″ x 14″ duct which measures 9′ 2″ between the plenum chamber and the end of the duct. It is not necessary to break down trunk line A into sections of different sizes because it is the same size its entire length.

6-6. Trunk line B is 37′ 6″ long and has sections of different sizes; therefore, it should be broken down by sizes. Beginning at the takeoff from trunk line A, trunk line B has the following sections:

- 6″ for takeoff fitting reducing 18″ x 12″ to 18″ x 10″
- 3′ of 18″ x 10″ rectangular duct
- 12″ for an 18″ x 10″ to 16″ x 10″ transition
- 12′ 8″ of 16″ x 10″ rectangular duct
- 12″ for a 16″ x 10″ to 14″ x 8″ transition
- 9′ of 14″ x 8″ rectangular duct
- 12″ for a 14″ x 8″ to 12″ x 8″ transition
- 9′ 4″ of 12″ x 8″ rectangular duct

6-7. Trunk line C is 42 feet long and should be broken down into four sizes of ducts and three sizes of transitions. This breakdown will look similar to the breakdown made for truck line B in the preceding paragraph.

6-8. Now, breaking down of the system continues to the branch line ducts. In foldout 1 you can count 15 branch lines: 12 are 6 inches in diameter and 3 are 8 inches in diameter. Since the lengths differ, they must be measured to determine the breakdown into 6-inch and 8-inch sizes.

6-9. Starting with room 1, the 6-inch diameter branch lines are measured from the side of the trunk line to the center of the outlet and are broken down as follows:

Room 1, 7′ 8″ (6′ 11″ straight duct plus 9″ for the elbow)
Room 2, 7′ 7″ (6′ 10″ straight duct plus 9″ for the elbow)
Room 3, 7′ 6″ (6′ 9″ straight duct plus 9″ for the elbow)
Room 5, 7′ 6″ (6′ 9″ straight duct plus 9″ for the elbow)
Room 6, 7′ 7″ (6′ 10″ straight duct plus 9″ for the elbow)
Room 7, 7′ 8″ (6′ 11″ straight duct plus 9″ for the elbow)
Room 8, 7′ 8″ (6′ 11″ straight duct plus 9″ for the elbow)
Room 9, 7′ 7″ (6′ 10″ straight duct plus 9″ for the elbow)
Room 10, 7′ 6″ (6′ 9″ straight duct plus 9″ for the elbow)
Room 11, 7′ 6″ (6′ 9″ straight duct plus 9″ for the elbow)
Room 12, 7′ 7″ (6′ 10″ straight duct plus 9″ for the elbow)
Room 13, 7′ 8″ (6′ 11″ straight duct plus 9″ for the elbow)

6-10. The 8-inch-diameter branch lines are located in the latrine and two hallways. They are broken down as follows:

Latrine 6′ 6″ (5′ 6″ for straight duct plus 12″ for elbow)
Hallway 7′ 6″ (6′ 6″ for straight duct plus 12″ for elbow)
Hallway 7′ 6″ (6′ 6″ for straight duct plus 12″ for elbow)

6-11. Now let's return to the heater room and determine the dimensions of the supply plenum and the return air duct. To determine these dimensions, it is necessary to use foldout 1 (¼″ = 1′ −0″ scale) and the heater room detail on foldout 2 (½″ = 1′ −0″ scale). Since the detail drawing is the larger scale and easier to measure, you can determine that the supply plenum is 24″ wide, 36″ high, and 24″ long.

6-12. The height of the return air duct (return air and outside air plenum) is shown on foldout 2, and the length is measured from end to end. The width is measured on foldout 1. The dimensions of the return air duct are 10′ 6″ of 36″ x 18″ rectangular duct.

6-13. In the preceding paragraphs we have broken the heating and air-conditioning duct system down into three trunk lines, fifteen branch lines, the supply plenum, and return air duct. These subsystems were then broken down into sections having the same dimensions. Now let's go to the next step, which is to break down the various sections into appropriate lengths (commonly called joints). For example, the 16″ x 10″ section of trunk line B will consist of several joints of 16″ x 10″ rectangular duct. *Determining the appropriate length of these joints depends primarily on the width of the duct.* Since the width of each duct section is shown on the working drawings, we can refer to figure 28 which shows the duct width, recommended gage of metal, type of joint connectors, length of each joint, and the bracing to be used. After determining the length of joints to use from the chart in figure 28, it is not difficult to determine how many joints are needed to make up a section.

6-14. At first glance it appears to be a matter of simple arithmetic to determine how many joints will be needed to make up a section (dividing section length by length of each joint). However, it is somewhat more complex, since the economical use of materials must be considered. This economy is achieved by selecting the right size of sheet metal, getting the most pieces out of each sheet, and using leftover pieces wherever possible. For example, the section of 6" round duct in room 1 (FO 1) is 6' 11" long. At first, this appears to require a sheet of metal 6 feet long and 18.8 inches wide; however, when other factors are considered, you will find that the best procedure is to make the 6-inch branch line in two 36-inch joints plus a 6-inch tap connection at one end and an 8-inch short joint at the other. In the following discussions you will learn why sheets 36 inches wide are best for this section of duct.

6-15. *Type of seam.* Determining what type of seam to use is an important part of the preliminary planning of a duct job because the seam allowances must be included in the patterns. The size of each pattern will determine the size of sheet to use. From the dimensions specified for the rectangular ducts in foldout 1, you can see that none of the joints will be too large to be made from a single sheet of metal. Thus, if each joint can be cut and formed from one sheet, each joint will require only one corner seam. Earlier in this course you learned that the Pittsburg lock seam is a good choice for a corner lock seam and that it can be made with a Pittsburg lock forming machine or with a cornice brake.

6-16. Determining the type of seam for the round ducts in foldout 1 is easy because grooved seams are most often used when a lock seam is desired. You should recall that grooved seams can be made with a Pittsburg lock forming machine or with handtools and a bar folder or cornice brake.

6-17. The corners of the transitions in foldout 1 are jointed with Pittsburg lock seams, and the number of seams will depend on how many pieces are used in each transition. Later in this chapter you will see how to use leftover pieces of metal to fabricate small items, such as transitions and short joints.

6-18. The branch lines in foldout 1 include 6- and 8-inch elbows that connect the round, straight duct to the ceiling diffusers. Each elbow is made of five pieces, or gores. Each gore is rolled up into a circular shape 6 or 8 inches in diameter, and the ends are fastened with a grooved seam.

6-19. Other components of the duct system of foldout 1 that will require seams include the round takeoff fittings for the branch lines (dovetail seams), the covers for the ends of the trunk lines (standing seams), and the top for the plenum chamber (standing seams).

6-20. *Type of joint connection.* Another part of preliminary planning is to determine the type of joint connection to be used throughout the duct system because the amount of material required for the additions to the patterns must be known to determine the size of sheets to use. According to figure 28, rectangular duct joints up to 24 inches wide can be made on 35-inch centers and should be connected with standing S-and-drive slips. Figure 28 also shows that rectangular duct joints which measure 12 inches wide by 8 inches high can be made for 7' 11" centers and can use a different type of S-and-drive slips. Now looking at foldout 1, you can see that only one duct is wider than 24 inches. This is the return air duct, which is 36 inches wide.

6-21. To determine joint connections for round duct, you need not refer to a chart because it is common practice to use a slip joint connection which is made with a crimping machine. Slip joints usually require an allowance for a 1½-inch crimp. This allowance is needed to figure the material required to make the round ducts. Dovetail seams are used to connect the round ducts to the rectangular trunk lines.

6-22. Other joint connections which must be determined for the duct system in foldout 1 include the tapped connections for the takeoff fittings that join rectangular duct of different dimensions and the V-grooves used to connect the gores of elbows. These V-grooves form lock joints between the gores when the gores are assembled. The V-grooves are made with an elbow edging machine, which was discussed in Volume 2 of this course.

6-23. *Type of bracing.* Determining bracing for the duct system shown in foldout 1 is not difficult, as you may have already noticed in the chart of figure 28. Since most of the rectangular ducts in this system are less than 24 inches wide, you can see that the type of bracing recommended is the cross brake. Only the return air duct is wider than 24 inches, and it will not require as much bracing as the chart indicates because it is installed on the floor and has support throughout its length. If the return air duct is made on 35-inch centers, the standing S-and-drive slips and cross braking will provide sufficient bracing. The round duct in the branch lines is not long enough to require bracing.

6-24. **Selecting Sheet Metal.** From the information in the preliminary planning of the duct system, you can determine what kind of sheet metal to use, as well as thickness, sheet size, and quantity. At this time you may want to review the portion of Volume 1 of this course that pertains to sheet metals.

6-25. *Kind of material.* Most heating, air-conditioning, and ventilating ducts are made

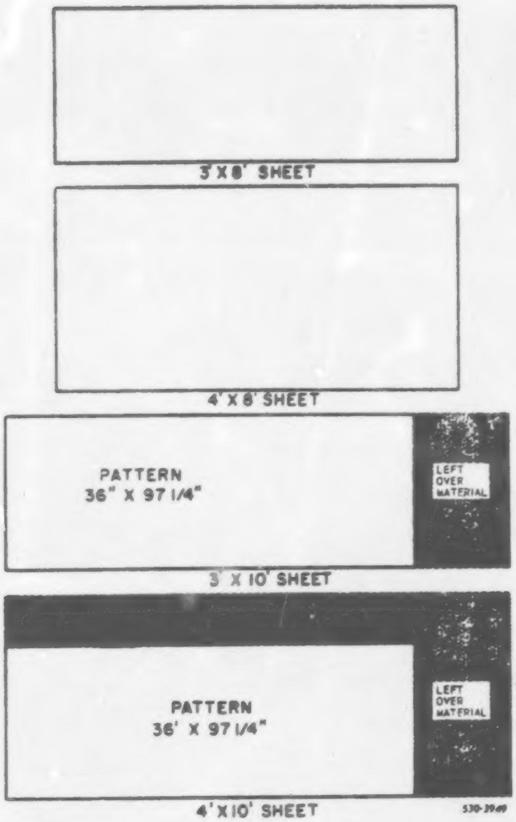

Figure 52 Selection of sheet sizes.

from galvanized sheet iron. This is true for the duct system shown in foldout 1 for several reasons. The air supply system is installed above the ceiling, there is no requirement for minimum weight which could be gained with aluminum, and there is no requirement for the extra corrosion resistance of stainless steel. However, there will be sufficient exposure to moisture (condensation) to rule out the use of black iron and to require the corrosion resistance of galvanized sheet iron. Galvanized sheet iron has a smooth surface, which is necessary for minimum friction loss as air is forced through the ducts. Also, galvanized sheet iron is available in various sizes and gages and at a reasonable cost. The return air duct will not be exposed to excessive condensation; but since it is installed at floor level, it should also be made of galvanized sheet iron.

6-26. *Thickness of material.* The recommended thickness or gage of sheet metal to use for the rectangular ducts shown in foldout 1 can be found in figure 28. The thickness of galvanized sheet iron for round ducts can be determined from the following list (For aluminum duct, increase the thickness of each of the following by 2 gages):

- For diameters up to 13 inches, use 26-gage galvanized.
- For diameters over 13 inches to 33½ inches, use 24-gage galvanized.
- For diameters over 33½ inches to 67½ inches, use 22-gage galvanized.

6-27. **Size and Quantity of Sheets.** Galvanized sheet iron is available in various sizes; however, the most frequently used sizes for duct construction include 3- and 4-foot widths in 8- and 10-foot lengths, as shown in figure 52. Although this may lead you to think that duct joints will usually be 8 or 10 feet long, this is not true because most rectangular duct joints are made in 3- or 4-foot lengths. The perimeter of a duct joint is usually greater than 4 feet and will be made in one piece with one corner seam. For example, a 20" x 14" joint that is 47" long will require a piece of sheet metal that is 48" x 69¼" (including seam and connector allowances), which should be made from a sheet 4 feet wide and 8 or 10 feet long. The length of the sheet selected depends on how the leftover material can be used.

6-28. Another reason for using sheets in 3- or 4-foot widths is that minimum bracing is needed. A look at figure 28 will quickly remind you that longer joints require more bracing than short ones. Figure 28 will also remind you that joints are often listed as "on 35-inch centers" or "on 7-foot 11-inch centers." This is because the length on working drawings is usually listed as the distance from center to center of the connectors at each end of the joint. A joint 36 inches long will have ½-inch allowance at each end for the S-and-drive slips and therefore will measure only 35 inches center to center.

6-29. In figure 52 a 36" x 97¼" pattern is to be made. Of the four available sheet sizes, the two 8-foot sheets are too short; therefore, the choice is between the 3' x 10' and 4' x 10' sheets. The leftover pieces are indicated by the dotted lines. You can see that the best choice is probably the 3' x 10' sheet. However, the choice really depends upon how the leftover material can be used.

6-30. *Trunk line A and plenum.* In figure 53 we have made a breakdown of trunk line A from foldout 1. This shows how trunk line A is divided into joints and takeoff fittings. To break down a trunk line like this, *the first step* is to make a scale drawing of the plan view, showing only the outline of the trunk line. Since trunk line A is connected to the supply plenum of the

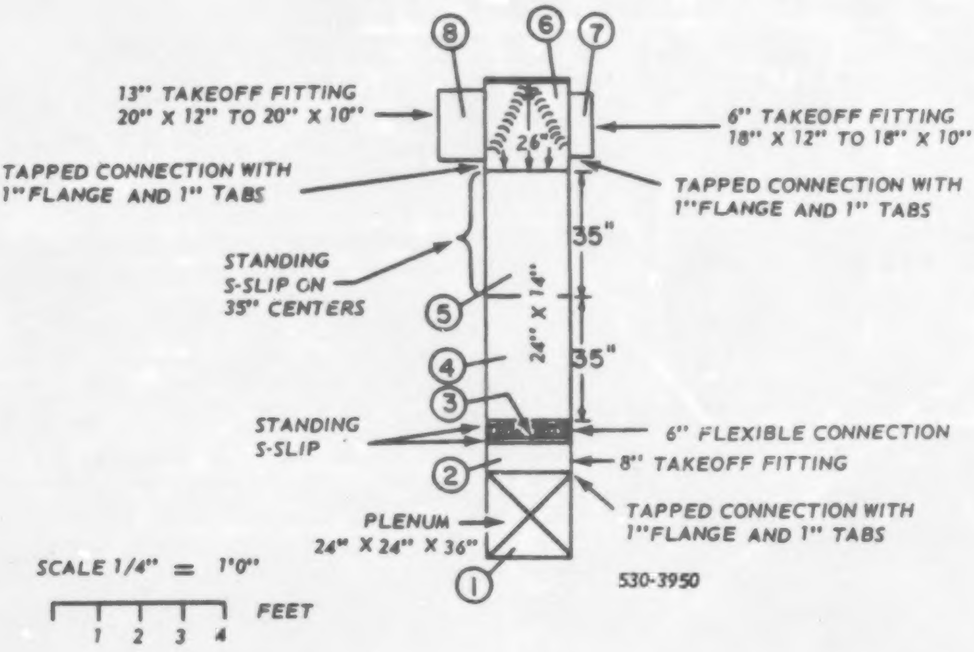
⑧
⑥
⑦
13" TAKEOFF FITTING
20" X 12" TO 20" X 10"
6" TAKEOFF FITTING
18" X 12" TO 18" X 10"
26"
TAPPED CONNECTION WITH
1" FLANGE AND 1" TABS
TAPPED CONNECTION WITH
1" FLANGE AND 1" TABS
35"
STANDING
S-SLIP ON
35" CENTERS
⑤
24" X 14"
④
35"
③
STANDING
S-SLIP
6" FLEXIBLE CONNECTION
8" TAKEOFF FITTING
②
PLENUM
24" X 24" X 36"
TAPPED CONNECTION WITH
1" FLANGE AND 1" TABS
SCALE 1/4" = 1'0"
①
530-3950
FEET
1 2 3 4

Figure 53. Breakdown of plenum and trunk line A.

heating and air-conditioning units, the plenum is also included in the drawing. As determined earlier in this chapter, the plenum is 24 inches wide, 36 inches high, and 24 inches long. Trunk line A is 24 inches wide, 14 inches high, and 9 feet 2 inches long. No joint connection allowances are needed for either the top or bottom of the plenum.

6-31. Since the height of the plenum is 36 inches, it is logical to lay out the pattern on a sheet that is 36 inches wide. Since the stretchout (including 1¼-inch Pittsburg seam allowance) is 97¼ inches, you must decide whether it should be made from an 8- or a 10-foot sheet. (Look at figure 52 and you will see the answer.) The top opening of the plenum is 24" x 24"; the plenum will have a cover (top) of the same size, that is attached with 1-inch standing seams. The allowance for the standing seams on all four edges of the cover will require the pattern to be 28" x 28", which is larger than the leftover piece of the sheet just used for the plenum. It is good practice on large jobs like this to *not* cut the 28" x 28" from another whole sheet but to wait for a leftover piece from the next group of patterns, which in this example will be from trunk line A.

6-32. Thus far the material required for the two patterns has been determined, and you can see that the material requirements include one whole 3' x 10' sheet (with 36" x 22¾" left over) and another sheet from which the 28" x 28" can be made. This indicates that some sort of bookkeeping system is needed to identify the parts by size and quantity, to list the sheet from which the pattern will be cut, and to indicate how many and what size of sheets are needed. Figure 54 is an example of how such a record can be kept. You will also find that it is helpful to make a sketch of each sheet of metal, showing how the patterns should be arranged to avoid unnecessary waste. Figure 55 shows how the trunk line and plenum can be made from four sheets. The sequence for determining the size and quantity of sheets required is to: (1) make a drawing, such as figure 53, to show the dimensions of the duct and joints; (2) start a materials required list, such as that shown in figure 54; and (3) make sketches of the sheets, such as those shown in figure 55.

6-33. The materials needed for the plenum and for the plenum cover are the first two entries made on the materials required list (fig. 54). Although the illustration shows the chart filled out, let's start from the beginning and learn how it was developed. By doing this you will learn how to determine what size sheets and how many will be required for the job. You can later use similar procedures for other jobs. First write "plenum" in the Item Identification column, followed by the dimensions and number of patterns needed. Since we have already determined that a

3′ x 10′ sheet should be used. enter this information in the Source of Materials column. At this time a sketch is made of sheet number 1 (fig. 55), showing the plenum as 36″ x 97¼″ with a single piece 22¾″ x 36″ left over. This piece is not large enough to make the 28″ x 28″ plenum cover. (A leftover piece from joint 4 in sheet 2 will be suitable to make the plenum cover.) The second entry in figure 54 is for the plenum cover, including its size and the quantity needed. The source of material will be entered later.

6-34. Trunk line A has the same dimensions (24″ x 14″) for its entire length; therefore, its stretchout, including Pittsburg lock seam allowance, will be 77¼ inches. Its length, as previously determined, is 9′2″, which can be divided into joints as shown in figure 53. Beginning with *joints 4 and 5*, you should enter the pattern dimensions and requirements on lines of the materials chart (fig. 54). These patterns, including allowances, are each 36″ x 77¼″ and should be made from two 3′ x 10′ sheets with two 36″ x 42¾″ pieces left over. (One of these leftover pieces can be used to make the plenum cover.) These dimensions are determined by making sketches of sheets 2 and 3, as shown in figure 55. Looking at figure 53, you will see that joints 4 and 5 occupy only 70 inches of the total length (110 inches) of trunk line A. This leaves 40 inches for joints 2, 3, and 6.

6-35. The size of joint 6 is determined by the size of its two takeoff fittings and the size of joints 2 and 3. Remember, only 40 inches are

.MATERIALS REQUIRED				
ITEM IDENTIFICATION	MATERIAL NEEDED FOR PATTERNS (INCLUDING ALLOWANCES)		SOURCE OF MATERIAL	
	Dimensions	Quantity	Sheet Number	Size
PLENUM	36″ X 97 1/4″	1	1	3′ X 10′
Plenum Cover	28″ X 28″	1	2	
TRUNK LINE A	—	—	—	—
Joint 4	36″ X 77 1/4″	1	2	3′ X 10′
Joint 5	36″ X 77 1/4″	1	3	3′ X 10′
Joint 6	26 1/2″ X 77 1/4″	1	4	3′ X 10′
End Cover (Joint 6)	18″ X 28″	1	4	—
Joint 2	11 1/2″ X 39 1/4″	2	3	—
Joint 7 Top and Bottom Pieces	9 1/2″ X 20″	2	4	—
Joint 7 Side Pieces	9 1/2″ X 12 1/2″	2	2 and 4	—
Joint 8 Top and Bottom Pieces	11 1/2″ X 22″	2	1	—
Joint 8 Side Pieces	11 1/2″ X 12 1/2″	2	3 and 4	—
Joint 3 Metal Strips	3 1/2″ X 77 1/4″	2	4	—
Joint 3 Asbestos Cloth	6″ X 77″	1	From Roll	—
Standing S-Slips	5 1/2″ X 23 3/4″	2	1	—
Standing S-Slips	5 1/2″ X 23 3/4″	3	2	—
Standing S-Slips	5 1/2″ X 23 3/4″	2	3	—
Standing S-Slips	5 1/2″ X 23 3/4″	1	4	—
Drive Slips	2 1/4″ X 16″	7	4	—
Drive Slips	2 1/4″ X 16″	1	2	—

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Figure 54. Materials required for plenum and trunk line A.

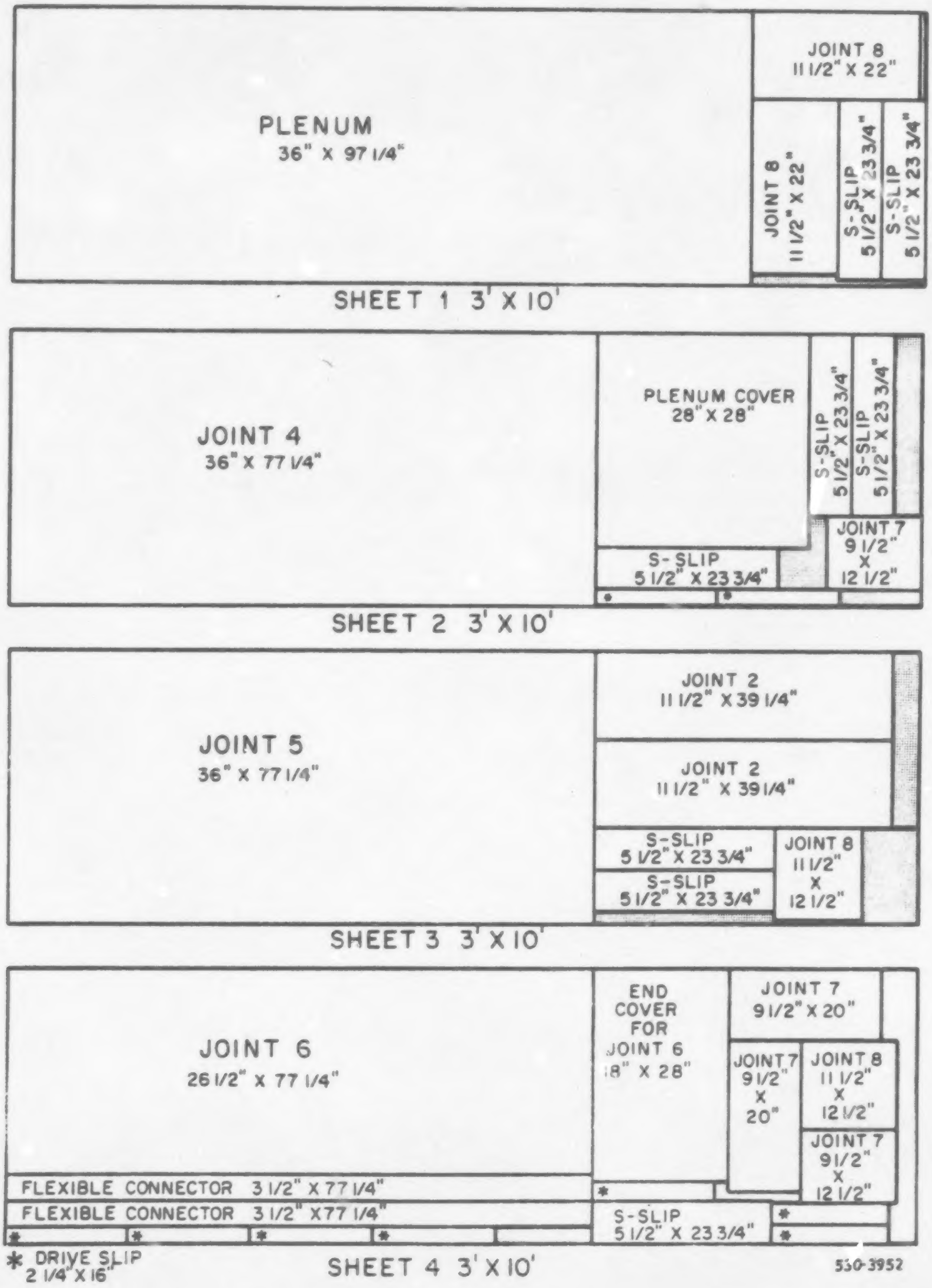

PLENUM
36" X 97 1/4"
JOINT 8
11 1/2" X 22"
JOINT 8
11 1/2" X 22"
S-SLIP
5 1/2" X 23 3/4"
S-SLIP
5 1/2" X 23 3/4"
SHEET 1 3' X 10'
JOINT 4
36" X 77 1/4"
PLENUM COVER
28" X 28"
S-SLIP
5 1/2" X 23 3/4"
S-SLIP
5 1/2" X 23 3/4"
JOINT 7
9 1/2"
X
12 1/2"
S-SLIP
5 1/2" X 23 3/4"
SHEET 2 3' X 10'
JOINT 5
36" X 77 1/4"
JOINT 2
11 1/2" X 39 1/4"
JOINT 2
11 1/2" X 39 1/4"
S-SLIP
5 1/2" X 23 3/4"
S-SLIP
5 1/2" X 23 3/4"
JOINT 8
11 1/2"
X
12 1/2"
SHEET 3 3' X 10'
JOINT 6
26 1/2" X 77 1/4"
END COVER FOR JOINT 6
18" X 28"
JOINT 7
9 1/2" X 20"
JOINT 7
9 1/2"
X
20"
JOINT 8
11 1/2"
X
12 1/2"
JOINT 7
9 1/2"
X
12 1/2"
FLEXIBLE CONNECTOR 3 1/2" X 77 1/4"
FLEXIBLE CONNECTOR 3 1/2" X 77 1/4"
S-SLIP
5 1/2" X 23 3/4"
* DRIVE SLIP
2 1/4" X 16"
SHEET 4 3' X 10'
530-3952

Figure 55. Determining size and quantity of sheet metal for trunk line A and plenum

available for joints 2, 3, and 6. In figure 53 you can see how these 40 inches are used to make joints of appropriate sizes. Joint 6 is shown to be on 26-inch centers and is connected to joint 5 with S-and-drive slips. The pattern for joint 6 measures 26½" x 77¼", which will require part of another whole sheet (sheet 4, figure 55), with two leftover pieces. One of these pieces is large enough to make the 18" x 28" end cover for joint 6. The joint 6 entry is now made in figure 54 and the sketch made on figure 55 for joint 6 and its end cover. This end cover is to be installed with standing S-seams similar to those for the plenum cover.

6-36. Joint 2 in figure 53 is a 24" x 14" takeoff fitting which, with seam and connection allowances, will have pattern dimensions of 11½" x 77¼". This pattern can be made from the leftover material from joint 5 (sheet 3) if joint 2 is made in two pieces (11½" x 39¼") with two Pittsburg lock seams. The line entry for joint 2 is now made in figure 54 and the sketches made on sheet 3 of figure 55.

6-37. Joint 7 in figure 53 is a takeoff fitting 6 inches long which reduces from 18" x 12" to 18" x 10". It has a tapped connection at one end and S-and-drive connections at the other. Since this transition tapers on two sides, it should be made in four pieces with four Pittsburg lock seams. The patterns for the pieces are each 9½ inches wide (6-inch length plus 3-inch allowance for the tapped connection and ½-inch allowance for the S-and-drive connection). The two patterns for the top pieces are 9½" x 20" (2 inches are allowed to make the pockets for the Pittsburg lock seams). The two patterns for the side pieces are 9½" x 12½" (½ inch is allowed to make the ¼-inch flanges for the Pittsburg lock seams). These four pieces are entered as line items in figure 54. Notice in the sketches that the piece left over from the joint 6 end cover (sheet 4) is large enough to make two top pieces 9½" x 20". Notice that the two 9½" x 12½" side pieces are made from sheets 2 and 4.

6-38. Joint 8 in figure 53 is a takeoff fitting 8 inches long, which reduces from 20" x 12" to 20" x 10". It is the same shape as joint 7 except for different dimensions. Joint 8 will require four pieces and four Pittsburg lock seams. The two 11½" x 22" pieces for the top and bottom can be made from the leftover piece from the plenum (sheet 1). The two 11½" x 12½" side pieces can be made from leftover pieces from sheets 3 and 4.

6-39. Joint 3 is a flexible connection made of asbestos cloth and metal. The connection is 6 inches long, 24 inches wide, and 14 inches high. Figure 56 shows how the asbestos cloth is connected to metal strips which connect to the S-and-drive slips of joints 2 and 4. Notice how the metal strips hold the cloth in double folds. The material needed for this flexible connection includes a piece of asbestos cloth 6 inches wide and 77 inches long (76-inch perimeter plus 1-inch allowance for the stitched lap seam). The two pieces of metal are 3½ inches wide and 77¼ inches long. The asbestos cloth is available in bulk lengths in various widths, including 6-inch width. The 3½-inch-wide metal strips can be made from the 9½" x 77¼" piece left over from sheet 4. These entries are recorded in the materials required list (fig. 54).

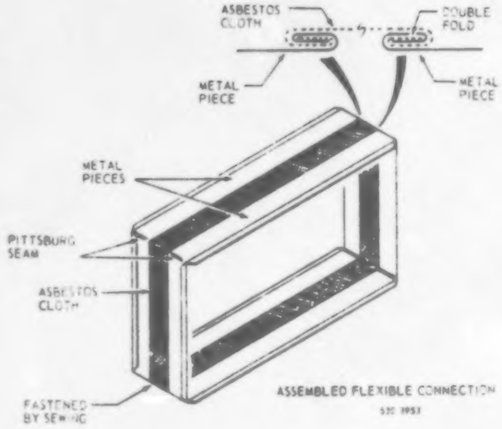


Figure 56. Flexible connection (joint 3) used in trunk line A.

6-40. The last step in determining size and quantity of material for trunk line A involves the standing S-slips and drive slips that connect the joints. In figure 53 you can see that S-and-drive slips are used in four places. This will require eight standing S-slips that need 5½" x 23¾" of metal each. The eight drive slips will need 2¼" x 16" of metal each. According to the sketches in figure 55, seven drive slips can be made from sheet 4 and one can be made from sheet 2. These entries are recorded in the materials required list (fig. 54).

6-41. Sometimes all of the pieces cannot be made from the sheets, as in this example of trunk line A. It may be necessary to wait and get the additional material from leftover pieces of the next duct, which in this example of the duct system shown in foldout 1 will be trunk line B. In the preceding paragraphs you have learned how to determine the size and quantity of sheets needed for the patterns of trunk line A and the plenum. In the following paragraphs, similar

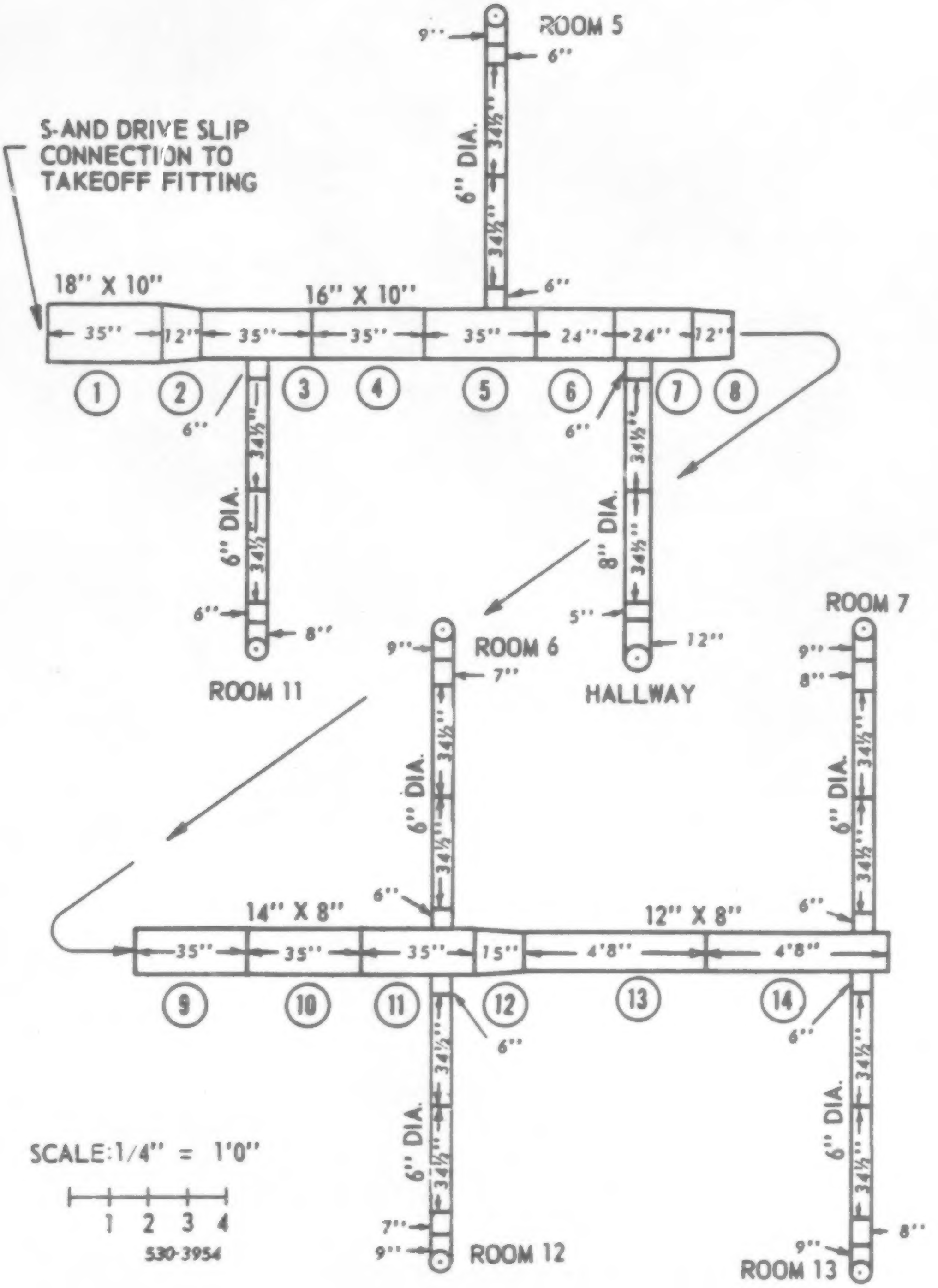

ROOM 5
9''
6''
6'' DIA.
34½''
34½''
6''
S-AND DRIVE SLIP
CONNECTION TO
TAKEOFF FITTING
18'' X 10''
16'' X 10''
35''
12''
35''
35''
35''
24''
24''
12''
①
②
③
④
⑤
⑥
⑦
⑧
6''
6'' DIA.
34½''
34½''
6''
8''
ROOM 11
6''
8'' DIA.
34½''
34½''
5''
12''
HALLWAY
ROOM 6
9''
7''
6'' DIA.
34½''
34½''
6''
ROOM 7
9''
8''
6'' DIA.
34½''
34½''
6''
14'' X 8''
12'' X 8''
35''
35''
35''
15''
4'8''
4'8''
⑨
⑩
⑪
⑫
⑬
⑭
6''
6''
6'' DIA.
34½''
34½''
7''
9''
ROOM 12
6'' DIA.
34½''
34½''
9''
8''
ROOM 13
SCALE:1/4'' = 1'0''
1 2 3 4
530-3954

Figure 57. Breakdown of trunk line B and branch lines.

procedures are used for the other trunk lines and branch lines.

6-42. *Trunk line B*. Earlier in this chapter we discussed the preliminary planning for a duct system. This included the system breakdown type of seams, joint connections, bracing, kind of material, thickness of material, and size and quantity of sheets. If you have carefully studied the text and illustrations, you will find that trunk line B is similar. Look at trunk line B in foldout 1 and notice that it has four different sizes of duct which are connected with transitions, that it has seven round duct branch lines, and that it is closed at the end with an end cover.

6-43. Now let's determine the size and quantity of sheets needed to plan and fabricate trunk line B. The first step is to make a scale drawing of the plan view. Figure 57 shows the complete breakdown of trunk line B and the branch lines. (Remember that the first step is to draw only the outside lines then add the joint connection lines and dimensions as the length of each joint is determined.) Although we have divided the trunk line into two parts in order to fit them on one page, it is recommended that your own drawings be made larger and that the trunk line be in a straight line. The four sections of trunk line B all have the same centerline.

6-44. To determine the length of the joints for trunk line B, draw the joint connection lines as shown in figure 57, beginning with joint 1, which is 35 inches long, center to center. You may think this should be 41 inches; however, 6 of the 41 inches are included in the takeoff fitting from trunk line A. Joint 1 has a perimeter of 56 inches which, with 1¼ inches added for the Pittsburg lock seam allowance, will make a stretchout of 57¼ inches. The allowance for the S-and-drive connections at each end of the joint is ½ inch. Thus the pattern, including allowances, for joint

MATERIALS REQUIRED				
ITEM IDENTIFICATION	MATERIAL NEEDED FOR PATTERNS (INCLUDING ALLOWANCES)		SOURCE OF MATERIAL	
	Dimensions	Quantity	Sheet Number	Size
TRUNK LINE B				
Joint 1	36" X 57 1/4"	1	1	3' X 10'
Joints 3, 4, and 5	36" X 53 1/4"	3	1, 2	3' X 10'
Joints 6 and 7	25" X 36"	2	3	3' X 8'
Joints 9, 10, and 11	36" X 45 1/4"	3	3, 4	3' X 8'
Joints 13, 14	41 1/4" X 4' 9"	2	5	4' X 10'
Joint 2 (Transition Top & Bottom)	13" X 20"	2	6	3' X 8'
Joint 2 (Sides)	10 1/2" X 13"	2	6	———
Joint 8 (Transition Top & Bottom)	13" X 18"	2	6	———
Joint 8 (Sides)	10 1/2" X 13"	2	6	———
Joint 12 (Transition Top & Bottom)	16" X 16"	2	6	———
Joint 12 (Sides)	8 1/2" X 16"	2	6	———
End Cover (Joint 14)	16" X 16"	1	6	———
Standing S-Slips	5 1/2" X 17 3/4"	4	7	3' X 10'
Standing S-Slips	5 1/2" X 15 3/4"	12	7	———
Standing S-Slips	5 1/2" X 13 3/4"	8	7	———
Standing S-Slips	5 1/2" X 11 3/4"	4	7	———
Drive Slips	2 1/4" X 12"	16	7	———
Drive Slips	2 1/4" X 10"	12	7	———

530-3955

Figure 58. Materials required for trunk line B.

1 will be 36" x 57¼", which can be made from a sheet of metal 3' x 10'. This information about joint 1 is recorded on the Materials Required List (fig. 58), and sketches are made showing how the pattern for joint 1 can be made from sheet 1. Figure 59 shows how these sketches should be made to determine the size and quantity of sheets.

6-45. Continuing with the larger joints of trunk line B, notice that joints 3, 4, and 5 have the same dimensions; therefore, a one-line entry can be made in the materials required list (fig. 58). Joints 6 and 7 are the same; joints 9, 10, and 11 are the same; and joints 13 and 14 are the same. In the sketches (fig. 59) notice that joints 1 and 3 are on sheet 1; joints 4 and 5 are on sheet 2; joints 6, 7, and 9 are on sheet 3; joints 10 and 11 are on sheet 4; and joints 13 and 14 are on sheet 5.

6-46. The transitions in trunk line B are joints 2, 8, and 12, as shown in figure 57. Transitions 2 and 12 are made in four pieces similar to the takeoff fitting 7 of trunk line A because only one of the two dimensions reduces. Transition 8 is also made in four pieces but is somewhat different because both dimensions reduce. Later in this chapter when you lay out the patterns for these transitions, you will find that the true length of the sloping sides requires 1/16-inch additional material. Look at sheet 6 in figure 59, and you can see that there is sufficient leftover material on the sheet to include the extra 1/16 inch needed for joints 2, 8, and 12.

6-47. The end cover for point 14, including allowance for 1-inch standing seams on each of the four sides, is sketched on sheet 6 of figure 59. The standing S-slips and drive slips are sketched on sheet 7 to show how time can be saved when making pattern layouts and cutting the materials if small, similar-shaped patterns like these are grouped together. Look at each of the seven sheets in figure 59 and you can see that several pieces are left over. These, along with the leftover pieces from trunk line A, can be used later for trunk line C and branch lines.

6-48. *Trunk line C.* In foldout 1 you can see that trunk line C is similar to trunk line B except for the dimensions. In our first breakdown of the duct system, we found that trunk line B is 36'6" long and that trunk line C is 42 feet long. Notice in foldout 1 that some of the sections have the same dimensions and that some of the material requirements from trunk line B can be used if the joints are the same length. The procedures for determining the size and quantity of sheets for trunk line C are similar to those used for trunk lines A and B. First, make a scale drawing of trunk line C, as shown in figure 60. Remember that this drawing begins with the outlines only and the joint connection lines are added one at a time.

6-49. *Branch lines.* Earlier in this chapter, when breaking down the duct system, you learned that trunk lines B and C had a total of twelve 6-inch and three 8-inch round duct branch lines. You also learned the length of each branch line. Now you are ready to determine how much material they will require and the size and quantity of sheets needed. As with the rectangular duct, the first step is to make scale drawings of the round duct branch lines, as we have done in figures 57, 60, and 61.

6-50. In figures 57, 60, and 61, notice that round joints on 34½-inch centers are used in most branches. Remember that the allowance for a slip joint is 1½ inches. Thus, you can see that sheets 36 inches wide will be a good choice. For this example, we are using a Pittsburg lock forming machine that will make 5/16-inch grooved seams, which will require a 1-inch seam allowance. Now figuring the size, you can see that the material needed for a 34½-inch joint in the 6-inch branches will be 19⅞" x 36".

34½"	center to center
+1½"	slip joint allowance
36"	length of joint
18⅞"	circumference of 6" duct ($C = \pi d$)
+1 "	grooved steam allowance
19⅞"	stretchout

The dimensions 19⅞" x 36" should be entered in the materials required list for the branch lines (not illustrated) before determining what size and how many sheets are required. In this example, you will find that six pieces 19⅞" x 36" can be made from a 3' x 10' sheet with ¾" x 36" left over.

6-51. The pattern dimensions for the 8-inch round duct joints are determined in the same manner as for the 6-inch joints. Notice in figures 57 and 60 that not all of the 8-inch diameter joints are on 34½-inch centers.

6-52. Continuing with determining materials for the branch lines, notice in figures 57 and 60 that all of the takeoff fittings are 6 inches long. These takeoffs are simply 6-inch joints of round duct fastened to the trunk lines with dovetail seams. You should recall from Chapter 1 how dovetail seams are made and that the seam allowance is ½ inch. Also notice in figures 57, 60, and 61 that the center-to-center lengths of the 6-inch elbows are 9 inches and the 8-inch elbows are 12 inches. This leaves one short joint in each branch line to compensate for the dif-

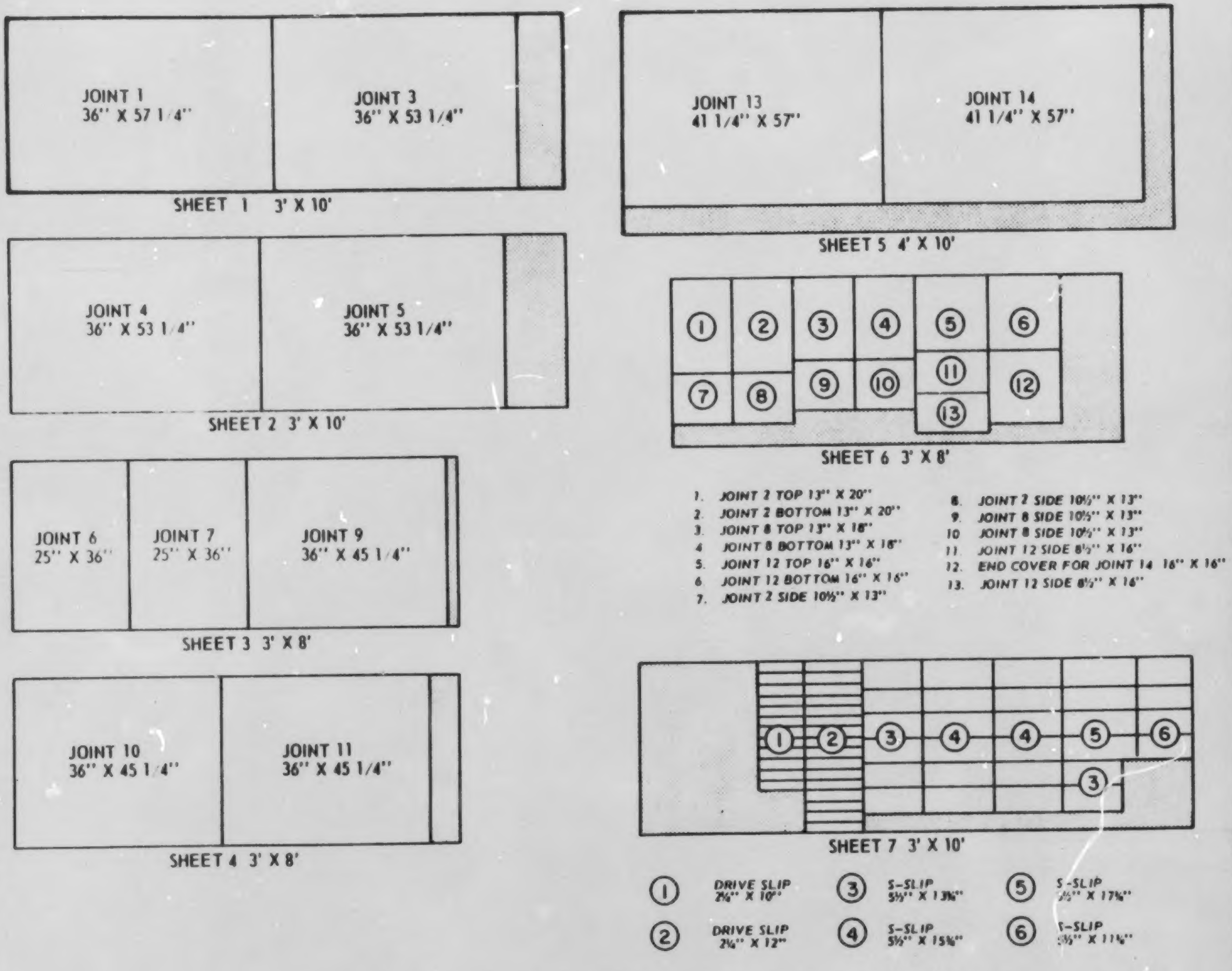

JOINT 1
36" X 57 1/4"
JOINT 3
36" X 53 1/4"
SHEET 1 3' X 10'
JOINT 13
41 1/4" X 57"
JOINT 14
41 1/4" X 57"
SHEET 5 4' X 10'
JOINT 4
36" X 53 1/4"
JOINT 5
36" X 53 1/4"
SHEET 2 3' X 10'
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬
SHEET 6 3' X 8'
1. JOINT 2 TOP 13" X 20"
2. JOINT 2 BOTTOM 13" X 20"
3. JOINT 8 TOP 13" X 18"
4 JOINT 8 BOTTOM 13" X 18"
5. JOINT 12 TOP 16" X 16"
6 JOINT 12 BOTTOM 16" X 16"
7. JOINT 2 SIDE 10½" X 13"
8. JOINT 2 SIDE 10½" X 13"
9. JOINT 8 SIDE 10½" X 13"
10 JOINT 8 SIDE 10½" X 13"
11. JOINT 12 SIDE 8½" X 16"
12. END COVER FOR JOINT 14 16" X 16"
13. JOINT 12 SIDE 8½" X 16"
JOINT 6
25" X 36"
JOINT 7
25" X 36"
JOINT 9
36" X 45 1/4"
SHEET 3 3' X 8'
JOINT 10
36" X 45 1/4"
JOINT 11
36" X 45 1/4"
SHEET 4 3' X 8'
① ② ③ ④ ④ ⑤ ⑥
③
SHEET 7 3' X 10'
① DRIVE SLIP 2⅛" X 10"
② DRIVE SLIP 2⅛" X 12"
③ S-SLIP 5½" X 13⅝"
④ S-SLIP 5½" X 15⅝"
⑤ S-SLIP 5½" X 17⅝"
⑥ S-SLIP 5½" X 11⅝"

Figure 59. Determining size and quantity of sheet metal for trunk line B and branch lines.

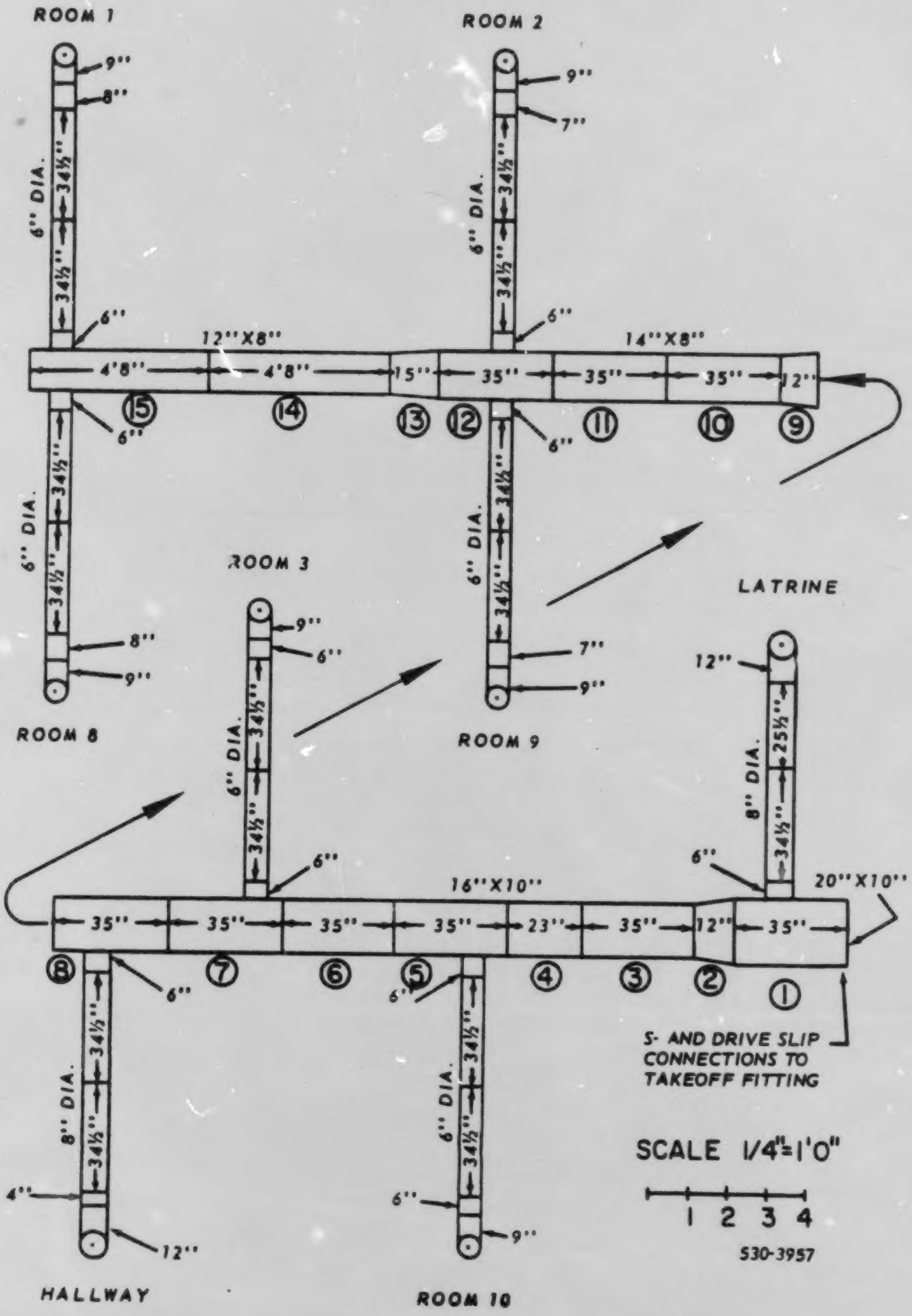

ROOM 1
ROOM 2
ROOM 3
ROOM 8
ROOM 9
LATRINE
HALLWAY
ROOM 10
6" DIA.
8" DIA.
9"
8"
7"
6"
4"
12"
34½"
25½"
12"X8"
14"X8"
16"X10"
20"X10"
4'8"
15"
35"
23"
12"
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬
⑭
⑮
S- AND DRIVE SLIP CONNECTIONS TO TAKEOFF FITTING
SCALE 1/4"=1'0"
1 2 3 4
530-3957

Figure 60. Breakdown of trunk line C and branch lines.

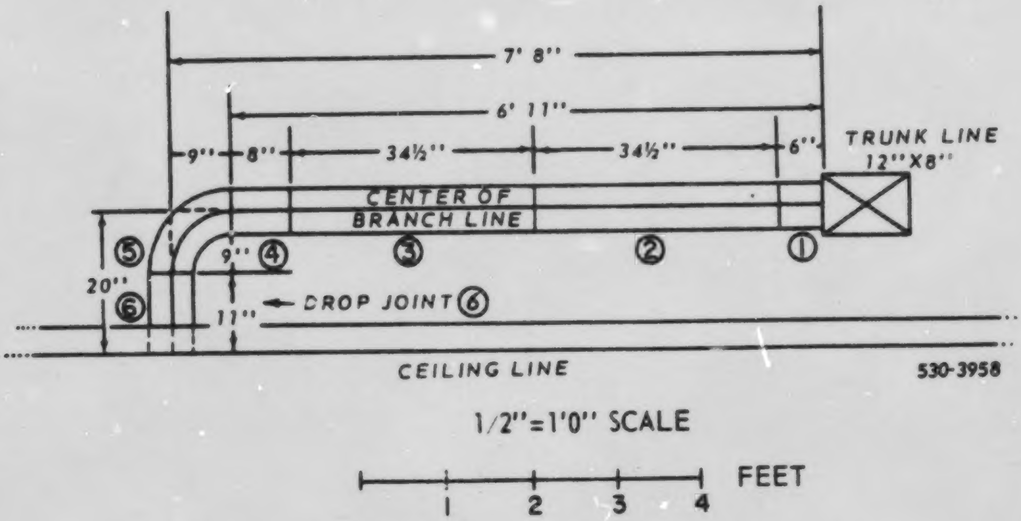


Figure 61. Elevation view of 6-inch branch line used in rooms 1, 7, 8, and 13.

ferences in the lengths of the branch lines. You have previously determined that the branch line lengths varied in different rooms because of the transitions in the trunk lines.

6-53. Later in this chapter we will discuss patterns for the 6-inch and 8-inch elbows. You will find that if the patterns for the five gores of each elbow are laid out side by side, the 6-inch elbow will require a 12¼" x 19⅞" piece of material and the 8-inch elbow will require a 15½" x 26⅛" piece of material. The branch lines shown in figures 57, 60, and 61 include twelve 6-inch elbows and three 8-inch elbows. With this information it is easy to determine how many sheets of metal will be needed to make the fifteen elbows.

6-54. The next parts of the branch to be determined are the joints that connect the elbows of the branch lines to the ceiling diffusers. Since these joints drop the flow of air from the previous centerline, they are sometimes called drop joints. Figure 61 shows a drop joint such as those used in the 6-inch branch lines in rooms 1, 7, 8, and 13 of foldout 1. The length of drop joints in 6-inch ducts is different from those in 8-inch ducts because of the differences in lengths of 6- and 8-inch elbows. The actual drop in this example is 20 inches, which is the distance from the centerline of the duct system to the ceilings of the rooms. (This distance is determined from foldout 2 by measuring the distance from the centerline of trunk line A to the ceiling. This distance continues to be 20 inches throughout the system because the centerline of this duct system is the same until the elbows in the rooms change the direction of airflow.) In figure 61, you can see that 9 inches of the 20-inch drop are taken up by the 6-inch elbow, leaving only 11 inches for the drop joint. However, this is the center-to-center length of the drop joint, which must be increased by 1½ inches for the crimped connection allowance, making an actual joint length of 12½ inches. In the rooms that have 8-inch elbows, the elbow extends 12 inches below the centerline, which requires the length of the drop joint to be shorter.

6-55. *Return air duct.* In foldout 2 you can see an elevation view of the return air duct (return air and outside air plenum) to the heating and air-conditioning system we have been discussing. Earlier in the chapter we broke down the return air duct and found the dimensions to be 18 inches high, 36 inches wide, and 9 feet 6 inches long. In figure 62 we have further broken the duct down into joints. Notice that joint 4 is located so that it will contain the multiblade damper. Determining the size and number of sheets for this duct is similar to that for the other rectangular ducts except that the dimensions are large enough to take nearly a whole 3' x 10' sheet for each joint. The stretchout including Pittsburg seam allowance is 109¼ inches. The ends of joints 1 and 4, as shown in figure 62, are plain and do not have flanges because the duct openings through the walls will be boxed in (framed) by the carpenters. The hall register and outside wall louver will be fastened to the wood framing. The joints are connected with S-and-drive slips between each joint.

6-56. **Selecting Registers, Grilles, and Diffusers.** The registers, grilles, and diffusers for a duct system are not difficult to select because most of the needed information is contained in the working drawings or blueprints. In the system we are describing, you can use foldouts 1 and 2 for selecting the registers, grilles, and diffusers. Each item can be added to the materials required lists (such as shown in figs. 54 and 58) and an appropriate statement made in the source of material column. For example, if any of the items are to be shop made, the estimated amount of material will be entered; however, if the items are to be purchased as factory-made units, the source column entry will be "Factory made."

6-57. The only register used in this system is the 18" x 36" return air register in the return air duct. The register is to be installed at floor level.

6-58. Two types of grilles are used, wall and door. Some of the grilles are 10" x 6", some are 12" x 6", and one is 12" x 8".

6-59. Each room and hallway has a round ceiling diffuser with an adjustable volume damper. Two sizes are used, 6-inch diameter and 8-inch diameter. These diffusers are the air supply outlets for the duct system. After installation, the dampers will be adjusted for the designated cfm (cubic feet per minute).

6-60. **Selecting Louvers and Dampers.** The louvers and dampers can also be selected from the information contained in foldouts 1 and 2. The system uses two louvers. One of these is 18" x 36" and is located on the outside air intake of the return air and outside air plenum. The other is 18" x 24" and is also located on the outside wall but has a different function: it allows filtered combustion air to enter the furnace room. Notice the description given on foldouts 1 and 2 concerning both of these louvers.

6-61. The system uses 16 volume dampers. In foldout 2 you can see that the multiblade volume damper is located in joint 4 of the return air and outside air plenum (return air duct). This damper must be installed in joint 4 when the joint is fabricated. The hand quadrant allows the damper blades to be adjusted to obtain the desired mixture of inside and outside air to be circulated through the heating and air-conditioning system. In foldout 1 you can see that 15 other volume dampers are located in the ceiling diffusers.

6-62. **Selecting Insulation.** Soft flexible blankets of glass fiber, with aluminum foil bonded to each side, are wrapped around the exterior of heating and air-conditioning ducts for thermal insulation

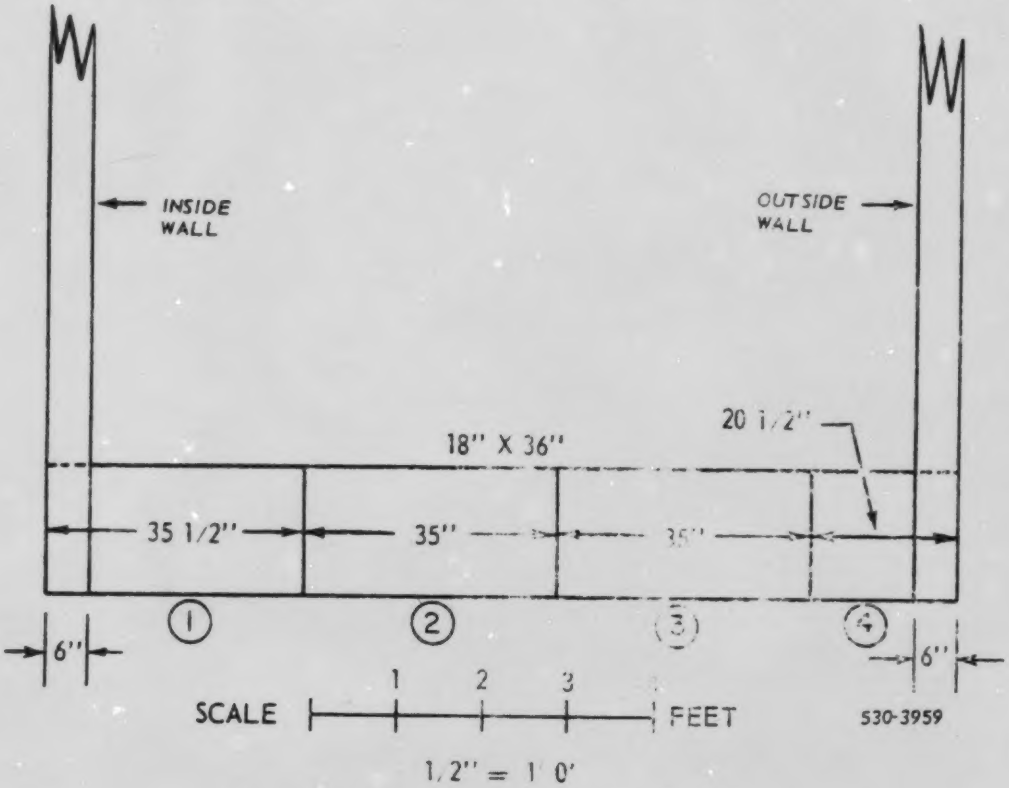


Figure 62. Breakdown of return air and outside air plenum.

The foil-backed insulation will prevent excessive cooling of heated air as well as excessive warming of cooled air as air passes through the duct system. Also insulation around the air-conditioning ducts will prevent condensation and dripping of moisture. Foil-backed insulation is available in rolls up to 100 feet long; in thicknesses of 1, 1½, and 2 inches; and in widths of 18, 24, 36, 48, and 72 inches. Rolls that are 48 and 72 inches wide have foil that extends 2 inches past both edges of the glass fiber, forming tabs which lap during installation. Rolls that are less than 48 inches wide usually have the 2-inch tab on one edge only.

6-63. When selecting insulation for a duct job, you will find the type and thickness described on the working drawing or blueprint. Look at note 2 in foldout 1 and notice that 1-inch foil-backed glass fiber insulation is specified. Your job is to determine the amount of insulation to be used, including length and width. For example, in foldout 1 the perimeter of trunk line A is 76 inches; the insulation is wrapped around the duct and joint with a fold (seam). This seam will require approximately 6 additional inches of material. If insulation 48 inches wide is used for trunk line A, each full sized piece should be 48 inches wide and 82 inches long. The number of pieces needed in this size is determined by the length of the duct. Trunk line A is 9′2″ long; therefore, two pieces 48″ x 82″ and one piece 14″ x 82″will be needed to cover trunk line A. The joints between these sheets are butt joints with the blankets fitting together and the foil tabs overlapping to make a lap joint. The end joint cover which is 24″ x 14″ will need a piece with 4 inches' allowance on each of the four sides for a lap joint.

6-64. Ducts such as the 12″ x 8″ section of trunk line B in foldout 1 can be insulated with one piece of foil-backed insulation 48 inches wide and 9 feet 4 inches long. In this case, there will be no joints and only one seam 9 feet 4 inches long. Thus you can see that it is easier, quicker, and cheaper to use single pieces when possible.

6-65. When determining the amount of insulation for a duct, you should also select the type of fastener to use and determine how many are needed. Although the seams and joints between sheets of foil-backed insulation are joined by folding the edges, other fasteners, such as staples, tape, adhesives, or wire, are also used. Soft zinc-coated 20-gage wire is commonly used around the joints to insure that the insulation blanket does not come off the duct. The amount of wire is determined by the number of joints and the perimeter of each, plus a wire band at each end of the duct. For example, in trunk line A three sheets of insulation (two 48″ x 82″ and one 14″ x 82″) are needed. This will require four wire bands around the two joints and two ends. Two inches are allowed for twisting the ends together; therefore, each band of wire should be 78 inches long (76 plus 2). Thus, the wire requirement for trunk line A is 78 inches multiplied by 4, for a total of 26 feet.

6-66. We have now explained the selection of materials for the heating and air-conditioning system shown in foldout 1. You have enough information to make a materials required list for the entire duct system, as well as sketches of the sheets of metal showing how each sheet can be cut with a minimum amount of waste.

7. Layout and Fabrication of Duct System Components

7-1. This section deals with the layout, cutting, notching, and forming of patterns into components. We will continue using the heating and air-conditioning duct system of foldout 1 to explain the procedures. By now you should have a good understanding of the system. It is suggested that you refer to the appropriate portions of Volumes 1 and 2 when necessary.

7-2. **Pattern Layout.** In Volume 1 of this course, you learned three methods of pattern development: parallel-line method, radial-line method, and triangulation method. Most of the ducts and components shown in foldout 1 have parallel sides, and patterns can be made by the parallel-line method. When looking at patterns illustrated in this chapter, remember that the bending instructions are written so that they will be on the inside of the joint when it is assembled.

7-3. *Rectangular duct joint patterns.* Figure 63 illustrates use of the parallel-line method to lay out the pattern for joints 4 and 5 of trunk line A (fig. 53); each joint is 24″ high x 14″ wide x 35″ long. Joints 2 and 6, also of trunk line A, are laid out the same except for length; joint 2 is on 8-inch centers, and joint 6 is on 26-inch centers. The 76-inch stretchout and 1¼-inch Pittsburg seam allowance are the same for all four of these joints except that joint 6 will have the ½-inch joint allowance on one end only.

7-4. The first step in laying out the pattern shown in figure 63 is to draw a straight line equal to the perimeter of the four sides, which in this case is 76 inches long. The five element lines are drawn 35 inches long, perpendicular to the stretchout line, and are spaced 14, 24, 14, and 24 inches apart. When the upper stretchout line is added, we have a 76″ x 35″ rectangle. Next, the Pittsburg lock seam allowances (1 inch at one end and ¼ inch at the other) are added. Then the ½-inch S-and-drive slip allowances are

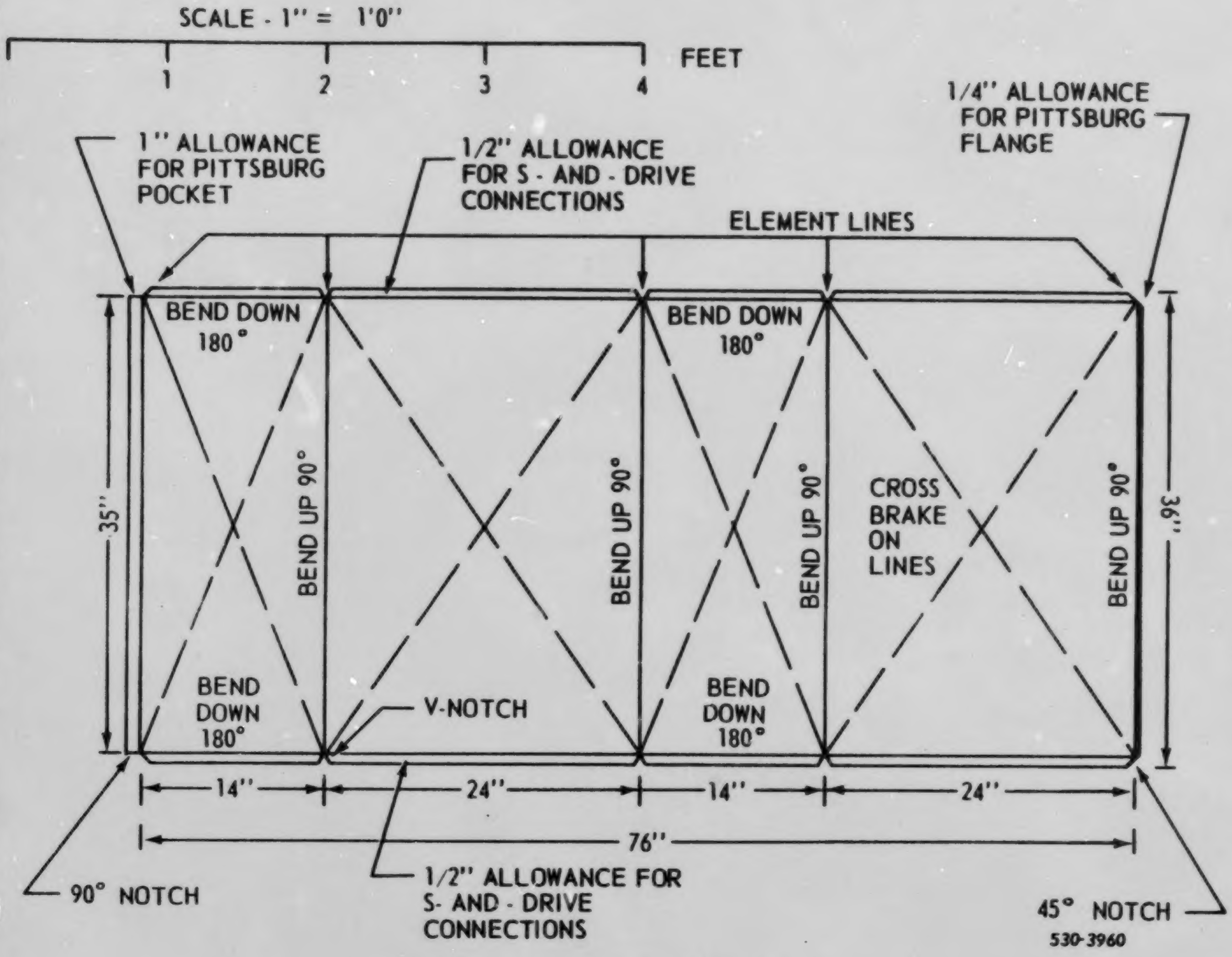

SCALE - 1" = 1'0"
1
2
3
4
FEET
1" ALLOWANCE FOR PITTSBURG POCKET
1/2" ALLOWANCE FOR S - AND - DRIVE CONNECTIONS
1/4" ALLOWANCE FOR PITTSBURG FLANGE
ELEMENT LINES
BEND DOWN 180°
BEND DOWN 180°
BEND UP 90°
BEND UP 90°
BEND UP 90°
BEND UP 90°
CROSS BRAKE ON LINES
35"
36"
BEND DOWN 180°
V-NOTCH
BEND DOWN 180°
14"
24"
14"
24"
76"
90° NOTCH
1/2" ALLOWANCE FOR S- AND - DRIVE CONNECTIONS
45° NOTCH
530-3960

Figure 63. Pattern for joints 4 and 5 of trunk line A.

added at each side for the joint connections. Don't forget that the 76-inch length of the stretchout will not be the length of the assembled joint. The joint will be 35 inches long, plus allowances. The final step is to mark the notches and cross brake lines, as shown in figure 63. Except for dimension differences, the pattern shown in figure 63 will be used for all rectangular joints with parallel sides that are shown in foldout 1.

7-5. *Round duct joint patterns.* All round duct joints of the branch lines are similarly made except for the dimensions. In figures 57 and 60, the most used sizes of round duct are 6-inch and 8-inch diameters, with lengths made on 34½-inch centers. Since the sides of the pattern are parallel, the parallel-line method of layout is used. Without allowances, the pattern for a 6-inch round joint on 34½-inch centers will be a rectangle 18⅞" x 34½", as shown in figure 64. The 18 ⅞-inch side of the pattern is the circumference of the 6-inch joint, and each edge has ½-inch allowance for the 5/16-inch grooved seam. Notice that one edge is to be bent up and the other is to be bent down. The length of the pattern is 34½ inches plus 1½ inches for the crimped slip joint, making a total length of 36 inches. The patterns for the other round duct joints in the branch lines are like this one, except for dimensions. The seam and connection allowances are the same for all round joints, except for the round joints that attach to the trunk lines with dovetail seams.

7-6. *Transition patterns.* Trunk lines B and C in figures 57 and 60 have three transitions each. These six transitions are similar, except for the two that have a reduction in both dimensions (joint 8 of trunk line B and joint 9 of trunk line C). Figure 65 shows the development of the patterns by the triangulation method for the sides, top, and bottom of the transition. The first step is to draw a plan view of the larger rectangle (16" x 10"), as shown in figure 65. Next, the smaller 14" x 8" rectangle is drawn inside the larger rectangle. Notice the corner diagonals and the centerlines. The next step is to project the vertical lines and make the top elevation view. The height of the transition is 12 inches; however, ½ inch straight must be left at each end so that the S-and-drive slips will connect properly. This makes the height of the elevation view (not counting the straight) 11 inches, as shown in figure 65. The *true* length (height) of the sloping sides when drawn to actual size (or scale) is 11 1/16 inches, making the total length of the pattern, including allowances, 13 1/16 inches.

7-7. The patterns for the top and bottom, before S-and-drive allowances are included, are identical to the elevation view except that the true length is used. To the top and bottom pattern in figure 65, ½-inch S-and-drive allowances are made at each end; and 1-inch Pittsburg seam pocket allowances are made at both edges. Notice how the straights are bent, one up 5° and one down 5°. Patterns for the two sides of the transition are identical. In figure 65 notice that the 1-inch straight on the widest end is 10 inches long, and the other straight is 8 inches long. These straights are 11 1/16 inches apart. Notice

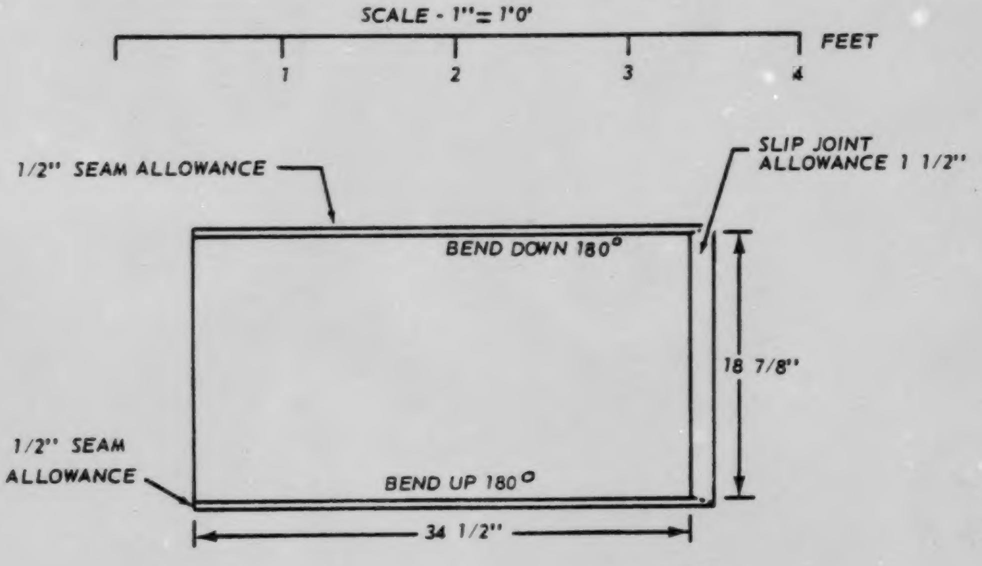


Figure 64. Pattern for a 6-inch round duct joint.

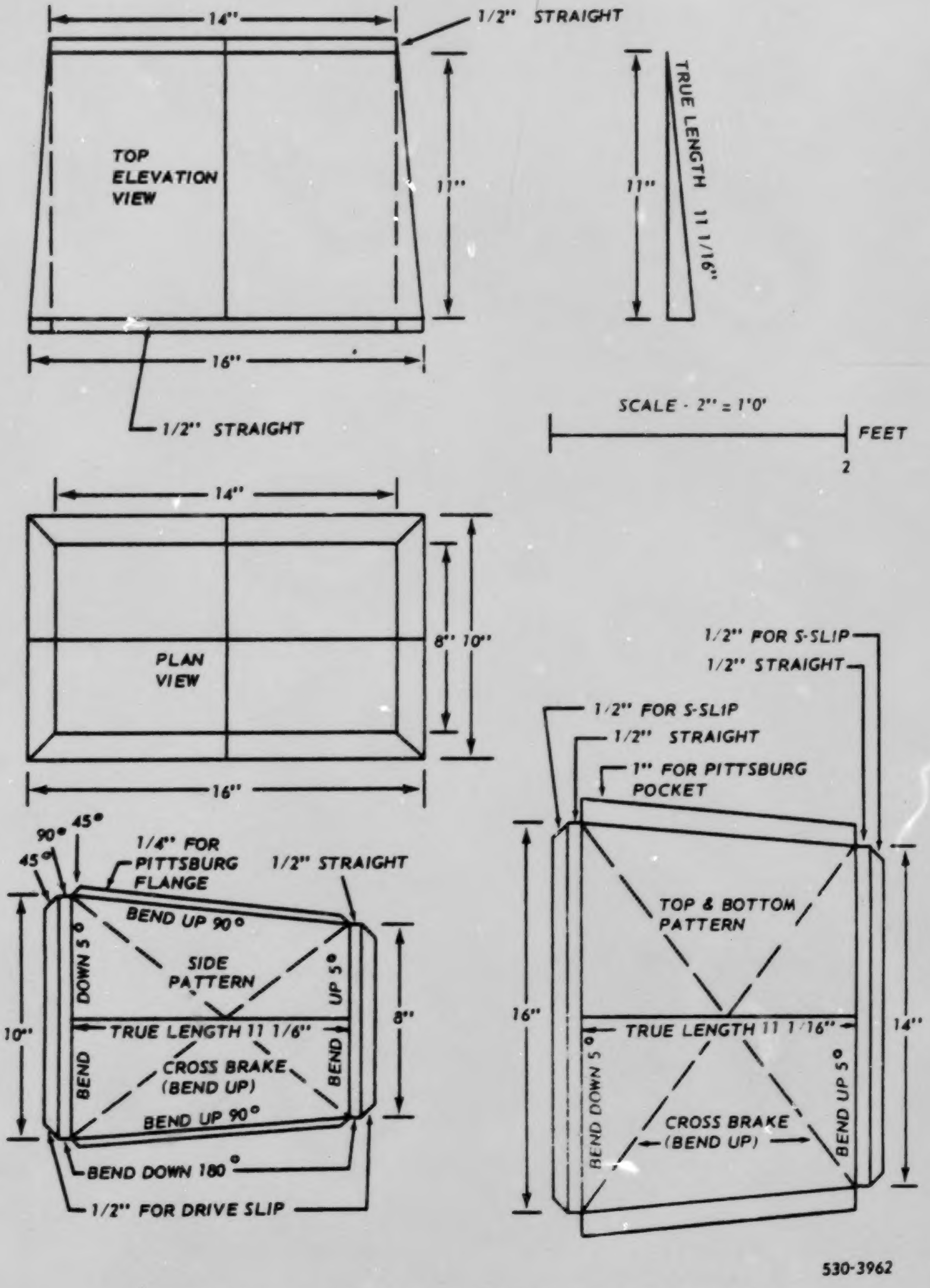

14"
1/2" STRAIGHT
TOP ELEVATION VIEW
11"
11"
TRUE LENGTH 11 1/16"
16"
1/2" STRAIGHT
SCALE - 2" = 1'0"
FEET
2
14"
PLAN VIEW
8"
10"
16"
1/2" FOR S-SLIP
1/2" STRAIGHT
1/2" FOR S-SLIP
1/2" STRAIGHT
1" FOR PITTSBURG POCKET
90°
45°
45°
1/4" FOR PITTSBURG FLANGE
1/2" STRAIGHT
BEND UP 90°
DOWN 5°
SIDE PATTERN
UP 5°
10"
TRUE LENGTH 11 1/6"
8"
BEND
CROSS BRAKE (BEND UP)
BEND
BEND UP 90°
BEND DOWN 180°
1/2" FOR DRIVE SLIP
TOP & BOTTOM PATTERN
16"
TRUE LENGTH 11 1/16"
14"
BEND DOWN 5°
CROSS BRAKE (BEND UP)
BEND UP 5°
530-3962

Figure 65. Patterns for 16" x 10" to 14" x 8" transition for trunk lines B and C.

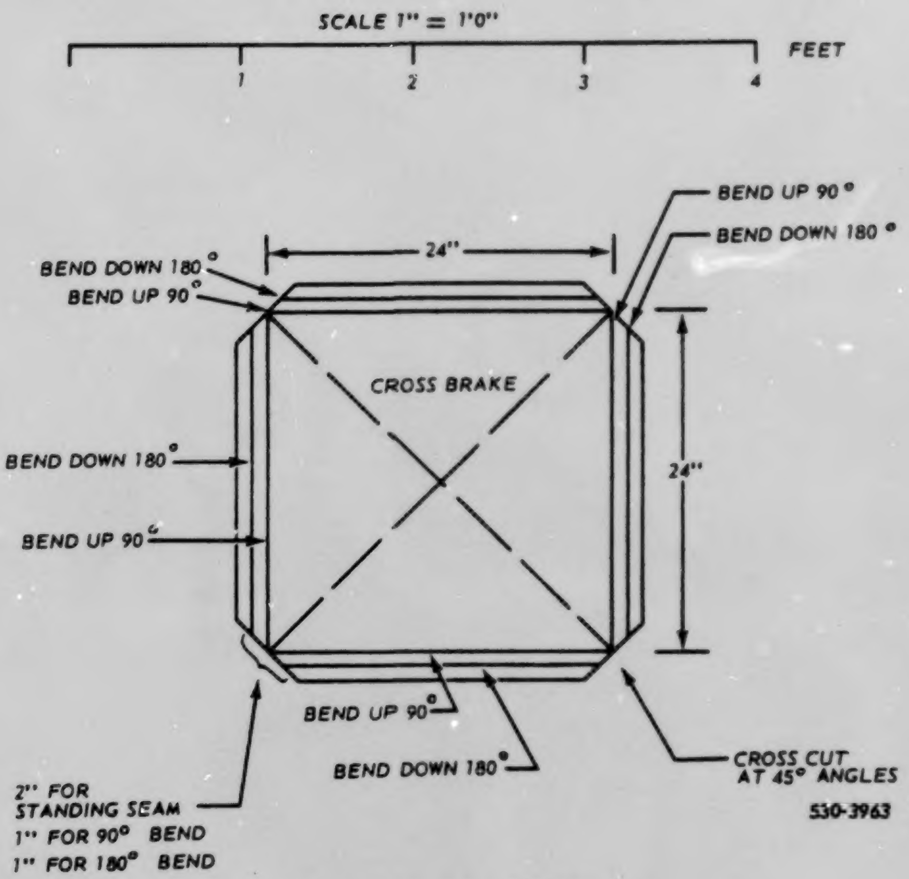

SCALE 1" = 1'0"
1
2
3
4
FEET
BEND UP 90°
BEND DOWN 180°
24"
BEND DOWN 180°
BEND UP 90°
CROSS BRAKE
24"
BEND DOWN 180°
BEND UP 90°
BEND UP 90°
BEND DOWN 180°
CROSS CUT
AT 45° ANGLES
530-3963
2" FOR
STANDING SEAM
1" FOR 90° BEND
1" FOR 180° BEND

Figure 66. Pattern for top of plenum.

the allowances of ½ inch at each end and ¼ inch at each side. In both patterns, the bending instructions, notching instructions, and cross brake lines are shown.

7-8. The patterns for transitions (joints) 2 and 12 of trunk line B and transitions 2 and 13 of trunk line C are developed in a similar manner, except that only the width of the transition reduces; the height remains the same.

7-9. *Plenum top and duct end patterns.* The pattern for the top of the plenum is shown in figure 66. This pattern, except for dimensions, is the same as the patterns for the end covers of trunk lines A, B, and C. These pieces have standing seams shaped like piece 2 of figure 7. With standing seams on all four sides, the 24" x 24" plenum top fits tightly over the 24" x 24" opening in the plenum, as shown in figure 67. When the top is installed, the standing seam acts as a stiffener and strengthens the plenum. In figure 66 you can see how 2 inches are allowed on all four sides for the standing seams. Also shown are the instructions for bending, corner notching, and cross braking. This pattern is developed by using the parallel line method of layout.

7-10. *Elbow patterns.* The branch lines of the duct system in foldout 1 have elbows that are similar, except for size. We will discuss the pattern development for a 5-gore elbow with a 6-

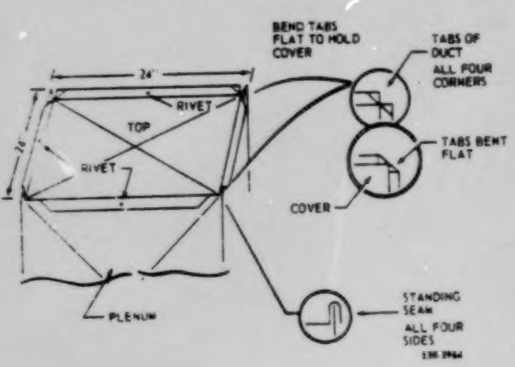

BEND TABS
FLAT TO HOLD
COVER
TABS OF
DUCT
ALL FOUR
CORNERS
24"
RIVET
TOP
24"
RIVET
TABS BENT
FLAT
COVER
PLENUM
STANDING
SEAM
ALL FOUR
SIDES

Figure 67. Standing seam used with plenum top.

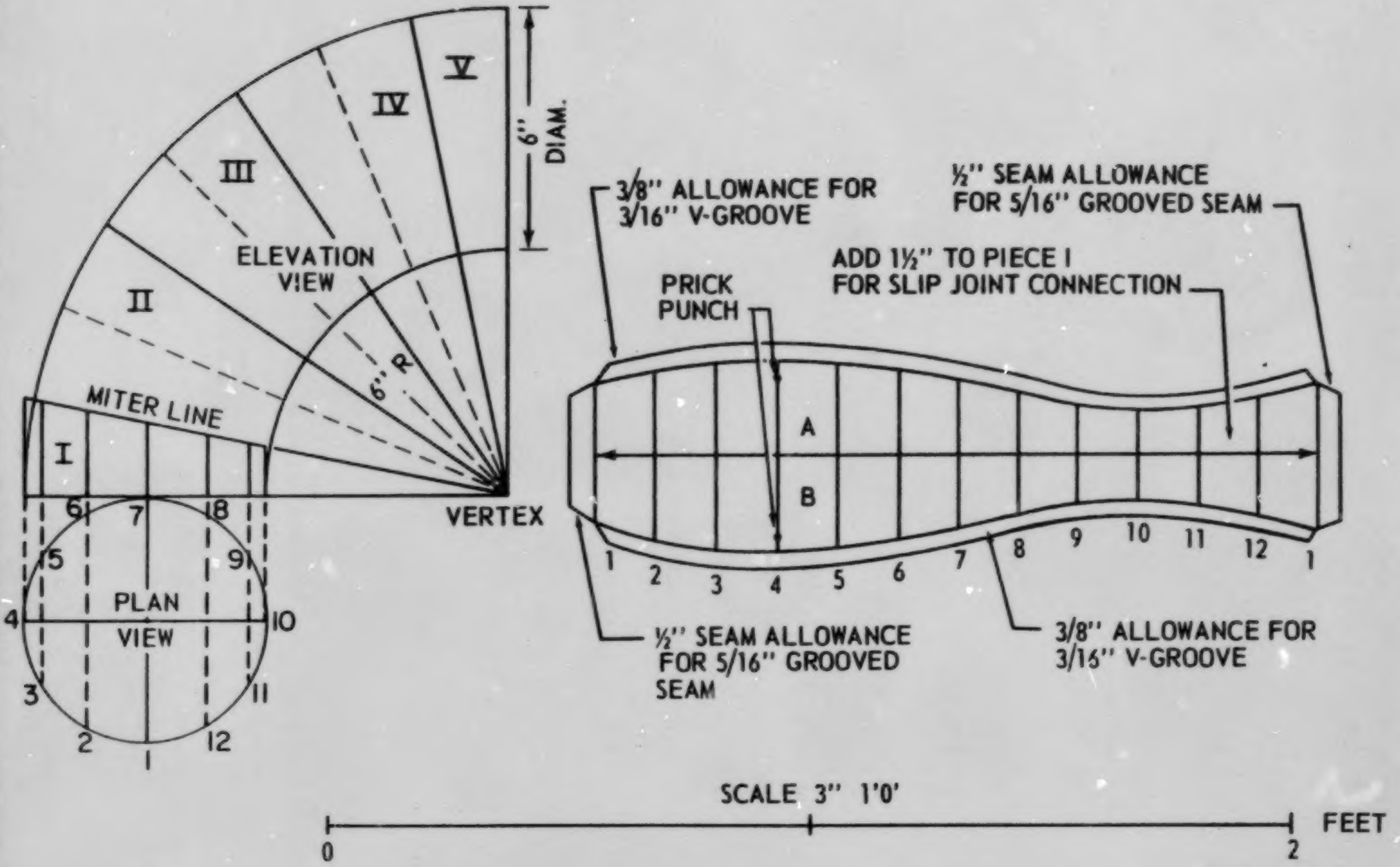

6" DIAM.
V
IV
III
II
I
ELEVATION VIEW
6" R
MITER LINE
VERTEX
PLAN VIEW
1
2
3
4
5
6
7
8
9
10
11
12
3/8" ALLOWANCE FOR 3/16" V-GROOVE
½" SEAM ALLOWANCE FOR 5/16" GROOVED SEAM
ADD 1½" TO PIECE I FOR SLIP JOINT CONNECTION
PRICK PUNCH
A
B
1 2 3 4 5 6 7 8 9 10 11 12 1
½" SEAM ALLOWANCE FOR 5/16" GROOVED SEAM
3/8" ALLOWANCE FOR 3/16" V-GROOVE
SCALE 3" 1'0'
0
2
FEET
530-3965

Figure 68. Pattern for gores of a 6-inch elbow.

inch diameter. The parallel line method is used as shown in figure 68. The first step is to develop the elevation view by beginning with a right angle, then striking a 6-inch throat radius and a 12-inch heel radius. Since this is to be a 5-gore elbow, the 90° arc is divided into eight equal parts by bisecting the 90° angle and the resulting 45° and 22½° angles with miter lines until there are eight angles of 11¼° each. Gores I and V are half-gores (11¼° each), and gores II, III, and IV are whole gores (22½° each). The lengths of the element lines are developed by drawing the plan view of a 6-inch circle, dividing it into 12 equal parts, then projecting lines upward to half-gore I. These projected lines passing through half-gore I represent the lengths of the element lines which will be made on each half of the stretchout.

7-11. The stretchout is begun with a working line equal in length to the circumference ($C = \pi \times D$) of the elbow, which in this example is 18⅞ inches. This working line is divided into 12 equal parts and is numbered as shown. Next, the lengths of the element lines from gore I are transferred to the stretchout. A pencil compass can be set to the length of element lines 1 and 7, and this distance is then transferred to the stretchout to mark each end of element lines 1, 7, and 1. The other element lines are transferred in a similar manner. These points are connected by the curved lines until the stretchout looks like figure 68. Remember, part A is a half-gore, and part B is a half-gore; together they make up a whole gore.

7-12. Each end of the stretchout in figure 68 has a ½-inch allowance for the grooved seam. The curved sides of the stretchout have ⅜-inch allowances for the $\frac{3}{16}$-inch V-groove connections. Half-gore I has 1½ inches added for the crimped slip joint connection. And last, two prick punch marks are made, as shown on element line 4. These punch marks will help make alignment easier during assembly of the gores.

7-13. *Turn vane patterns.* In an earlier chapter of this text, you learned how to determine width, length, spacing, and number of turn vanes in order to achieve maximum airflow through a 90° rectangular elbow. This information must be determined before making the pattern. Figure 69 shows an enlarged plan view of joint 6 of trunk line A, which contains two sets of turn vanes. This illustration is derived from the breakdown of trunk line A in figure 53. You should remember that for best airflow, turn vanes are spaced so that they will have an aspect ratio of 5. By using the formula $\frac{H}{W} = 5$ and substituting the height of the duct (14 inches), we get $\frac{14}{W} = 5$, or 2⅘ inches for the spacing between turn vanes.

7-14. The next step is to determine how many turn vanes are needed. This is done by dividing the 2⅘ (2.8) inch spacing into the length of the turn vane rows. As you can see in figure 69, the row for trunk line B has 8 turn vanes and the row for trunk line C has 9 turn vanes. In both computations, the actual number of turn vanes is a mixed number which has been rounded off to the nearest whole number. In this step you will also find that the curved part of the turn vane is 4½ inches and that each straight is 1½ inches. Thus, the dimensions for each turn vane are 7½" x 14". (If necessary, refer to figure 41 to refresh your memory concerning dimensions of turn vanes.) When the ¾-inch tab allowance is added to each end of the pattern, the total dimensions become 7½" x 15½", as shown in figure 69. Notice also that the ¾-inch tab allowance has been marked to show the slits, which are approximately 1 inch apart. During installation, these tabs are bent 90° and riveted to the top and bottom of the duct joint.

7-15. The patterns for components of the duct system can be made directly on the metal sheets; if several like items are needed, paper patterns or metal templates can be made. You should recall how patterns are transferred from paper patterns or metal templates.

7-16. **Cutting and Notching.** Patterns such as those shown in figures 63 through 69 contain information that you can use for cutting and notching. For example, figures 55 and 59 show how you can arrange the patterns on full-size sheets in such a way that minimum leftover pieces will remain after cutting. This information, combined with what you learned about sheet metal cutting equipment in Volume 2 of this course, should help you cut and notch patterns of almost any shape. Most of the patterns for this heating and air-conditioning duct system can be cut with squaring shears or unishears and notched with straight snips.

7-17. *Cutting patterns.* The patterns for joints 4 and 5 of trunk line A (fig. 63) are cut from sheets 2 and 3 (fig. 55) with power or manually operated squaring shears. After the pattern is scribed or marked on the 3' x 10' sheet, the sheet is placed in the squaring shears and cut along the 77¼-inch line. You will find that pieces up to 48 inches long can be cut to desired sizes by setting the front gage of the squaring shears. Pieces up to 24 inches long can be cut to desired sizes by using the back gage of the squaring shears. These gages are particularly

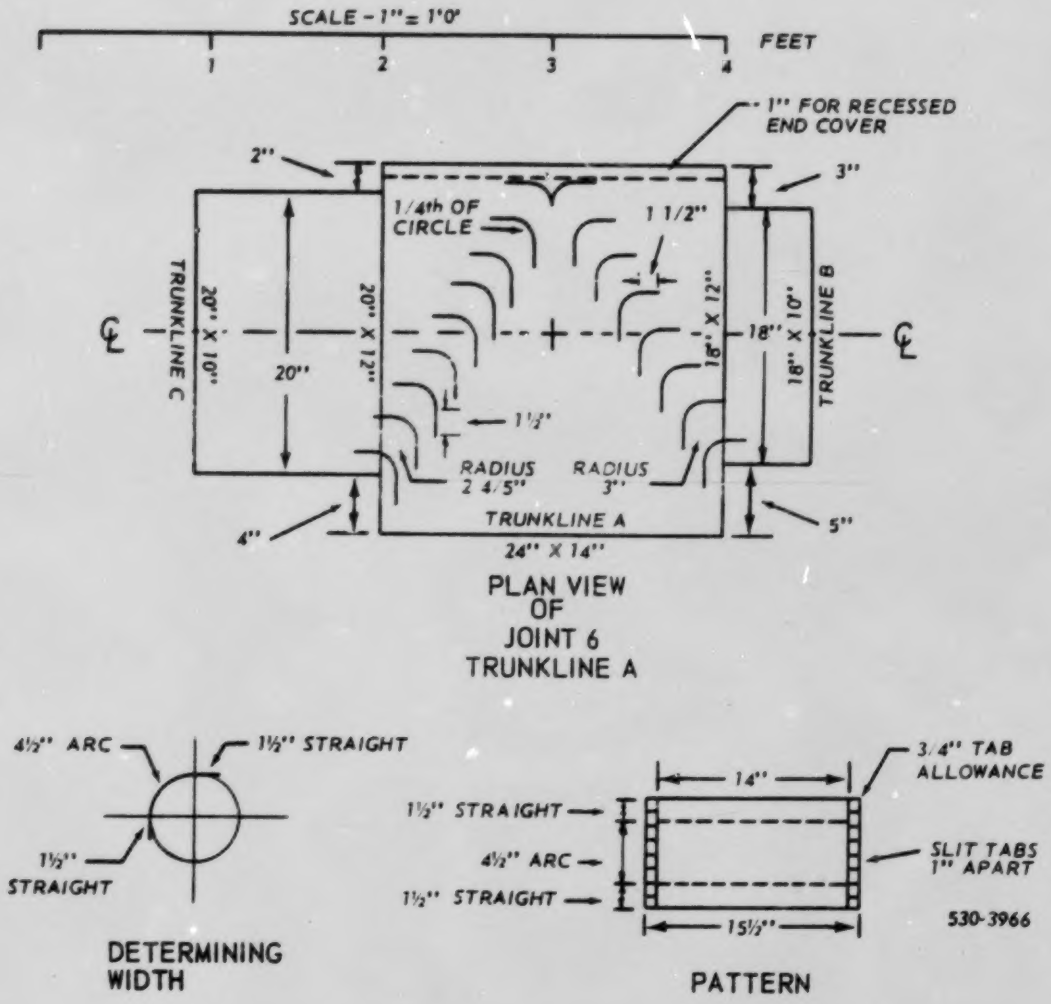

SCALE - 1" = 1'0"
1
2
3
4
FEET
1" FOR RECESSED END COVER
2"
3"
1/4th OF CIRCLE
1 1/2"
TRUNKLINE C
20" X 10"
20" X 12"
20"
℄
1½"
RADIUS 2 4/5"
RADIUS 3"
18" X 12"
18"
18" X 10"
TRUNKLINE B
℄
TRUNKLINE A
24" X 14"
4"
5"
PLAN VIEW OF JOINT 6 TRUNKLINE A
4½" ARC
1½" STRAIGHT
1½" STRAIGHT
DETERMINING WIDTH
14"
3/4" TAB ALLOWANCE
1½" STRAIGHT
4½" ARC
1½" STRAIGHT
SLIT TABS 1" APART
15½"
530-3966
PATTERN

Figure 69. Pattern for turn vanes.

helpful when several pieces of the same size are to be cut. When you are cutting patterns, be sure to include the seam and joint connection allowances. For example, in figure 63, the basic pattern size is 35" x 76"; however, when the allowances are included, the completed pattern will be 36" x 77¼". Several rectangular joints of the duct system in foldout 1 will require that holes be cut out for the takeoff fittings. The plenum will have a 24" x 14" opening to accept joint 2 of trunk line A. Joint 6 of trunk line A will have 18" x 12" and 20" x 12" openings for the takeoff fittings for trunk lines B and C respectively. Several joints in trunk lines B and C will have round openings to accept the 6- and 8-inch round takeoff fittings for the branch lines. The rectangular cutouts can be made with straight snips or portable unishears, and the round cutouts can be made with aviation snips or portable unishears. It is desirable to cut out openings for branch lines at the job site rather than in the shop.

7-18. The patterns for the round duct joints are easy to cut because they are rectangular in shape and do not have notches. Figure 64 shows the pattern for the 6-inch round joint used extensively in the branch lines. Notice that the size of the pattern, including allowances, is 19⅞" x 36". Patterns this size can be cut from 3' x 8' or 3' x 10' sheets with very little leftover material. Since several joints this size are to be made, time can be saved by setting the back gage of the squaring shears for 19⅞ inches and cutting all of the pieces from whole sheets of metal.

7-19. The patterns for the transitions shown in figure 65 are to be cut from sheet 6 in figure 59. Notice that we estimated the top and bottom patterns to be 13" x 18", but because of the true length of the sloping sides, the pattern will require $13\frac{1}{16}$" x 18". This additional $\frac{1}{16}$ inch can be obtained from the leftover space on sheet 6 (fig. 59) without affecting the other patterns. This same additional $\frac{1}{16}$ inch is needed for the two side patterns which will have an actual size, including allowance, of $10\frac{1}{2}$" x $13\frac{1}{16}$". Notice on sheet 6 in figure 59 that when this extra $\frac{1}{16}$ inch is cut for the top and bottom pieces, it will also provide the extra $\frac{1}{16}$ inch for the two side pieces. Sheet 6 can be easily cut with squaring shears by making the first 36-inch cut along the line between joints 2 and 8. The next 36-inch cut should be between the four pieces of joint 8, but allowing $13\frac{1}{16}$-inch width instead of the 13 inches shown. The next cut should make another piece $13\frac{1}{16}$" x 36". The other 36-inch cuts across sheet 6 are made as marked. Now, going back to the $26\frac{1}{8}$" x 36" piece cut for the transition, three cuts are needed to separate the four pieces of the transition and the $7\frac{1}{2}$" x $26\frac{1}{8}$" leftover piece. Remember to use the $13\frac{1}{16}$-inch measurement instead of the 13-inch measurement.

7-20. Cutting the elbow gores, shown in figure 68, is somewhat different because of the curved lines. These can be cut with straight snips, aviation snips, portable unishears, stationary unishears, ring and circle shears, or throatless shears. Since the duct system we are discussing has a large number of whole gores and half-gores to make, the portable or stationary unishears are the best choice of cutting equipment. Figure 70 shows how the patterns of the five gores of a 6-inch elbow can be arranged to be cut from one sheet of metal 19" x $19\frac{7}{8}$". If this group of patterns is made on

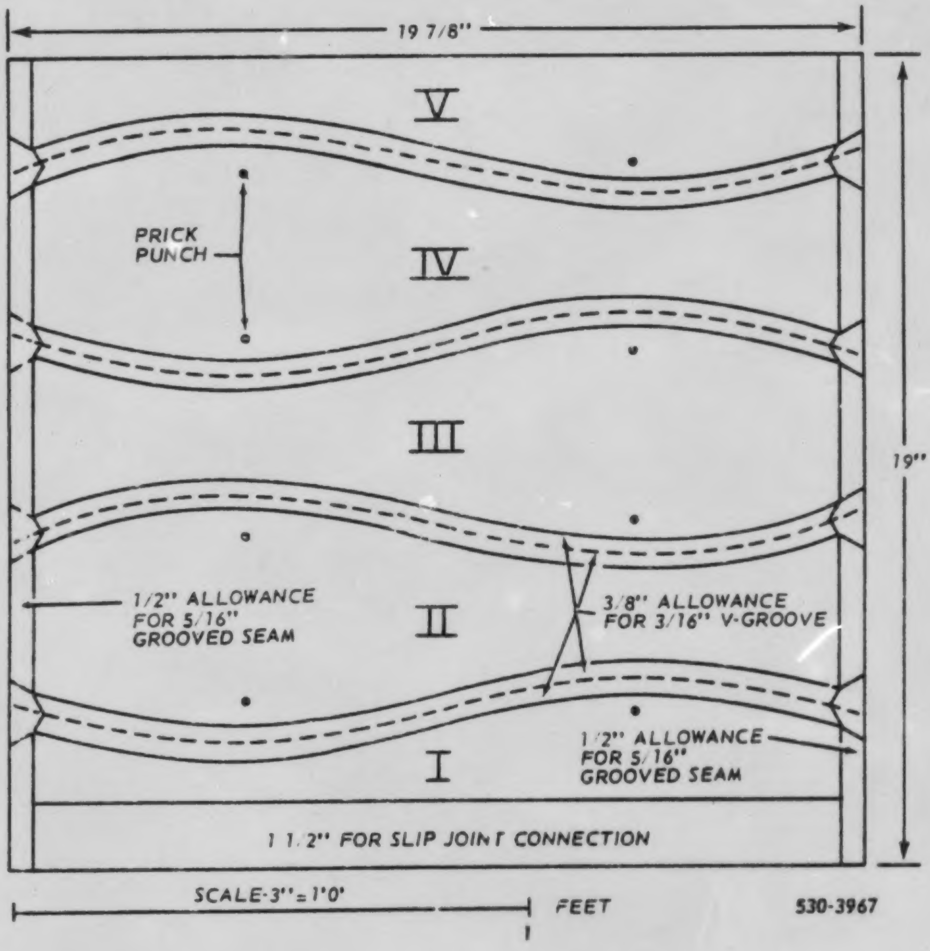

19 7/8"
19"
V
IV
III
II
I
PRICK PUNCH
1/2" ALLOWANCE FOR 5/16" GROOVED SEAM
3/8" ALLOWANCE FOR 3/16" V-GROOVE
1/2" ALLOWANCE FOR 5/16" GROOVED SEAM
1 1/2" FOR SLIP JOINT CONNECTION
SCALE-3"=1'0'
FEET
1
530-3967

Figure 70. Arrangement of gore patterns for cutting.

metal, unishears (or other appropriate cutting equipment) can be used to cut along the dotted lines between the patterns. After the first set is cut out of metal, gores I, II, and V can be used as templates for additional sets of patterns. Notice the dots on each gore that represent the location of the prick punch marks to be used during assembly of the elbow. Also notice that the 19" x 19⅞" dimensions include the seam and joint connection allowances.

7-21. *Notching patterns.* Slits and notches in patterns can be made with straight nips or throatless shears. The straight snips are used most often, but throatless shears have more leverage and require less effort. When using either of these, you must be careful not to make the cuts any longer than specified on the pattern. Notching is necessary so that sheet metal can be bent along the brake lines indicated on the pattern and to allow easier assembly of the Pittsburg lock seams, easier assembly of S-and-drive slip joint connections, and easier installation of the drive slips. V-notches and slant notches are cut at 45° angles, and square notches are cut at 90° angles. In figure 63 you can see examples of these notches. V-notches are used along the ½-inch allowances for the S-and-drive connections. Slant notches are used at each end of these ½-inch allowances. Square notches are used at each end of the 1-inch Pittsburg seam allowance. All of these can be cut with straight snips. Notice at the right-hand end of the pattern how one cut will make the slant notches for two sides at one time.

7-22. The pattern for the round duct joint in figure 64 does not require any notches because there are no cross bends to be made when the joint is assembled.

7-23. The patterns for the 16" x 10" to 14" x 8" transition shown in figure 65 have 45° and 90° notches at each corner. Although these notches are arranged somewhat differently from the notches for the rectangular-shaped duct, they are cut with the straight snips in the same manner.

7-24. The pattern for the plenum top in figure 66 has the corners cut at 45° angles. Notice how a single cut at each corner makes the slant notches for each adjoining side of the pattern plus slant notches for each 1-inch portion of the standing seam. These slant notches can be made with squaring shears or with straight snips.

7-25. The pattern for the elbow gore in figure 68 has 45° slant notches at each end of the ⅜-inch V-groove allowance. Notice that the ½-inch grooved seam allowance at each end of the pattern is also slant notched. These notches can be easily cut with straight snips.

7-26. The pattern for the turn vane shown in figure 69 has ¾-inch slits spaced approximately 1 inch apart so that the tabs can be bent 90° for fastening to the duct. When cutting slits like these, be careful to make all of the cuts exactly ¾ inch long so that the tabs can be bent properly.

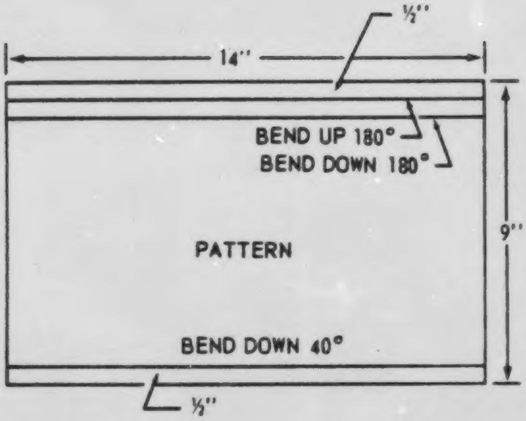
7-27. **Forming and Assembly.** Forming patterns into shape is the next step of fabricating sheet metal components. In Chapter 1 we described now the patterns shown in figure 32 were formed by a 1–2–3–4 sequence of operations: (1) cross braking, (2) seam allowance bending, (3) joint connection allowance bending, and (4) corner bends.

7-28. *Rectangular duct joints.* The regular sequence for forming sheet metal components is sometimes changed to make the operation easier. For example, to form the metal for the rectangular joints shown in figure 63 you will find it easier to do the folding in a 1–4–2–3 sequence because of the length of the stretchout. By forming the corners second, the metal is much easier to feed through the Pittsburg lock forming machine, because it is less difficult to handle the metal when the dimensions are 14" x 24" x 36" instead of 36" x 77¼". Look at figure 63 and see how the rectangular duct is formed. The first step is to use the cornice brake to bend the metal up along the cross brake lines. A 10° to 15° bend should be sufficient on the cross brake lines of any square or rectangular duct joint. Next, the cornice brake is used to make the 90° corner bends along three element lines and the ¼-inch Pittsburg flange line. This changes the flat sheet into a rectangular shape. Now resuming the regular sequence, step 2 is to make the bends for the Pittsburg seam pocket by feeding the 1-inch allowance for the pocket through the Pittsburg machine, as you learned in Chapter 1. Step 3 is to make the 180° bends for the drive slip connections by using a shop-made hand folder; however, a mallet and cornice brake can be used.

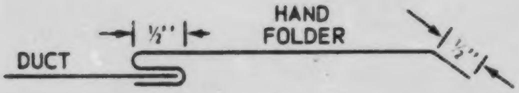
7-29. The rectangular duct we are discussing will need a hand folder that is 14 inches long. This hand folder can be made from a 9" x 14" piece of 18-gage metal, as shown in A of figure 71. In step B, the hand folder is placed over the edge to be bent. In step C, the ½-inch allowance of the duct joint is bent to 160°, and in step D the hand folder is turned around and the other end used for a spacer while the mallet is used to flatten the folded edge to 180°. This shop-made tool does the same job as a hand seamer except that it is long enough to bend (as in this example) the whole 14 inches in one operation. When making a hand folder, it is desirable to make several standard sizes that will bend edges that are 6", 8", 10", 12", 14", and 16" long.

7-30. Assembly of the 24" x 14" joint is quite simple, because all that remains to be done is to join the Pittsburg lock seam. The ¼-inch flange is inserted into the pocket and bent over (with a mallet), as shown in views B and C of figure 16. In figure 72, you can see the steps performed to "lock" the Pittsburg seam of a 35-inch joint. If the pocket of the seam is tight, it is necessary to insert the ¼-inch flange first at one end, as shown in step A of figure 72. The flange is started by hand, but after a few inches it may be necessary to use a hammer and a tool, such as a hand groover, to seat the flange firmly in the pocket. As the flange is inserted, the locking edge of the pocket is flattened as shown in step B of figure 72. After the flange is completely seated, the locking edge is flattened, as shown in step C. This completes the assembly of one joint of the rectangular duct. All of the other rectangular joints in foldout 1 are formed and assembled using similar procedures, except joint 6 and joint 2 of trunk line A. During assembly of joint 6, the turn vanes must be installed with rivets or sheet metal screws. Attachment of the two takeoff fittings to joint 6 is made by bending the tabs of the tapped connections. Attachment of joint 2, which is a takeoff fitting in trunk line A, is somewhat different because only the top and bottom have flanges and tabs. This is because the width of the plenum is the same as that of trunk line A. The two sides of the takeoff fitting are formed into an S-shape similar to an S-slip instead of a flanged tapped connection. Thus when joint 2 is attached to the plenum, the S will slip over the plenum sides and the tabs on the top and bottom are bent as with other tapped connections.

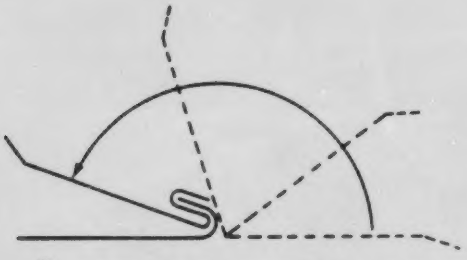
7-31. *Round duct joints.* Forming and assembly of a round duct joint is not difficult. Although round duct joints can be made with handtools, using several machines will make the job much easier. Squaring shears are used to cut the patterns, and the machines used for the forming processes include a Pittsburg machine for making the grooved seams (fig. 12), a slip roll machine for forming the sheet into a cylindrical shape, and a crimping machine and beading machine for making the crimp and bead of the slip-joint connection. The pattern shown in figure 64 is assembled with a grooved seam, which was discussed in Chapter 1. A Pittsburg machine can be used to turn back the 180° edges of the grooved seam, as shown in figure 12. Notice that one edge of the pattern must be turned up and the other edge must be turned down so that they



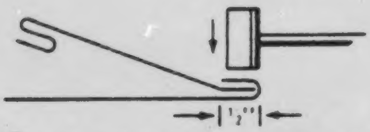
A. PATTERN MADE ON 18 GAGE METAL



B. HAND FOLDER PLACED ON EDGE TO BE BENT 180°



C. EDGE BENT TO APPROXIMATELY 160°



D. ½" DRIVE SLIP CONNECTIONS FLATTENED TO 180° WITH MALLET AND HAND FOLDER

530-3966

Figure 71. Hand folder to make 180° bends for ½-inch drive slip connections.

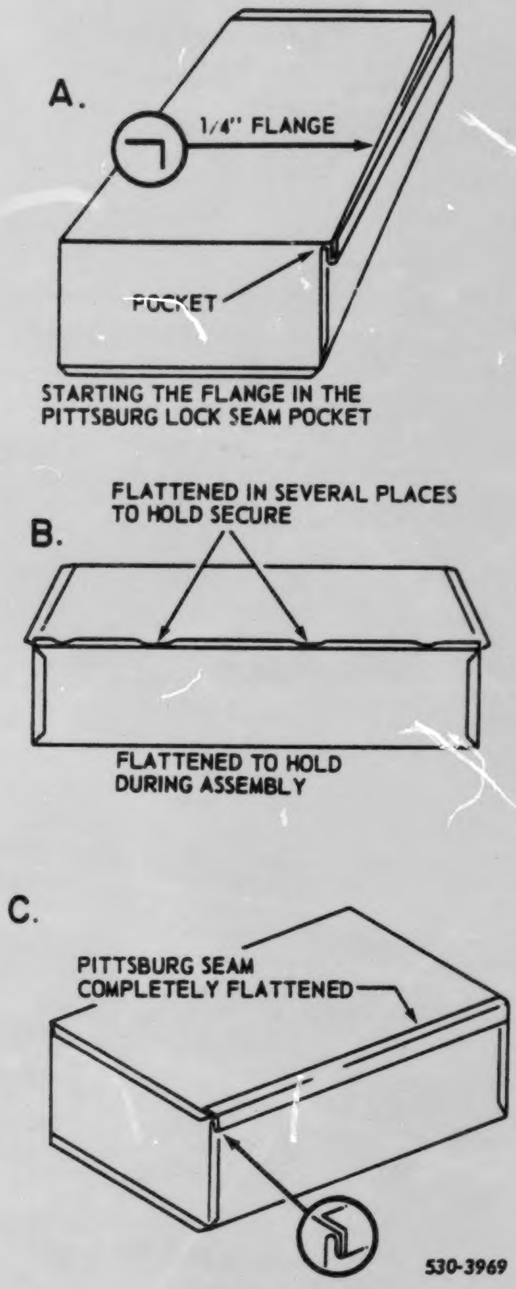

A.
1/4" FLANGE
POCKET
STARTING THE FLANGE IN THE PITTSBURG LOCK SEAM POCKET
B.
FLATTENED IN SEVERAL PLACES TO HOLD SECURE
FLATTENED TO HOLD DURING ASSEMBLY
C.
PITTSBURG SEAM COMPLETELY FLATTENED
530-3969

Figure 72. Assembly of a Pittsburg lock seam.

will lock when the piece is rolled up and joined. When the Pittsburg machine is used, the turned back edges will fit tight enough so that a mallet and hollow mandrel can be used to lock the seam. All of the round duct joints in foldout 1 are the same, and only the dimensions of the patterns differ. If you need to refresh your memory about the machines used, refer to Volume 2 of this course.

7-32. *Transitions.* Forming and assembly of the transition patterns shown in figure 65 are more complex than forming and assembly of round or rectangular joints because of the multiple bends required. However, if you first determine the best sequence for making the bends, the job is not difficult. Since these patterns are not too large, the standard 1-2-3 sequence of folding can be used. (Step 4 is not needed for this component.) Thus, the first step is to use the cornice brake to bend the metal up 10° to 15° along the cross brake lines on all four patterns. The second step is to make the Pittsburg seam pockets on the top and bottom patterns with the Pittsburg machine. The ¼-inch flanges on the side patterns are made with the cornice brake (or bar folder). By now you should realize why so much effort is made to cut the notches correctly. Good bends cannot be made if the notches are not made correctly. The third step is to make the 5° bends for the straight portions of the four pieces and to make the 180° bends for the drive slip connections. These can both be made with the cornice brake.

7-33. After the transition patterns are formed according to the instructions on the patterns, the four pieces are ready to be assembled by fitting and locking the Pittsburg lock seams in each of the four corners.

7-34. *Plenum top and duct ends.* Forming the top for the plenum and the ends for the three trunk lines is done by cross braking and making the bends indicated in figure 66 with a cornice brake, as illustrated in figure 8. These components do not require assembly because they are in one piece.

7-35. *Elbows.* Forming and assembly of the 6-inch and 8-inch elbows are some of the more complex operations of fabricating the duct system in foldout 1. The elbows each have five pieces which must be formed using the Pittsburg lock forming machine, slip roll forming machine, and elbow edging machine. (These were all discussed in Volume 2 of this course.) Figure 70 shows how the five gores look before they are cut and notched. From this illustration you can visualize how the five pieces will look after cutting and notching. The first step of forming is to use the Pittsburg machine to make the 180° bends at each end of the gores for the grooved seams. Each gore is then assembled by rolling it up into a circular shape and locking the 180° folds together in the same manner as for round duct joints. When the grooved seams are completed for all five gores, we are ready to make the V-grooves as shown in figure 73. In step A notice

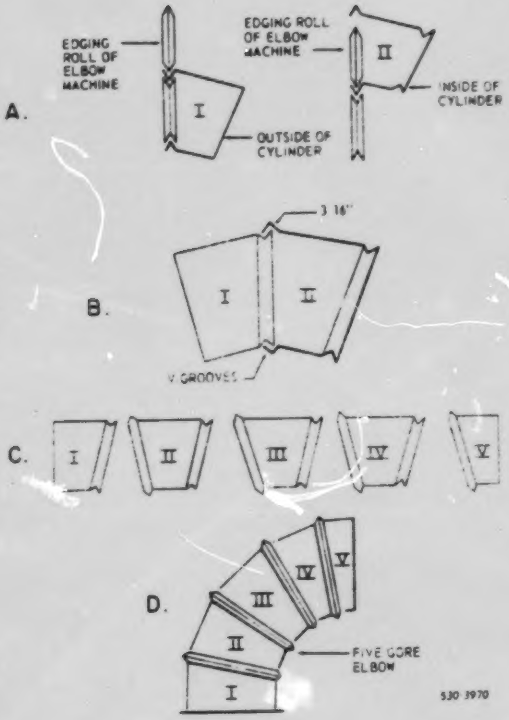


Figure 73 Forming V-grooves to assemble gores of an elbow.

how the first gore is placed in the elbow edging machine to make a groove with the V on the inside. Notice that the second gore is placed between the rolls so that it will have the V-groove on the outside. The second gore has one inside and one outside groove. In step C of figure 73, notice how the inside and outside V-grooves alternate. Step B shows how the V-grooves overlap when the gores are assembled; the V-groove of the second gore has been spread slightly so that it will slip over the V-groove of the first gore. When the gores are assembled, the outside V-groove is tightened by placing the gores on the edge of a bench stake and using a tinner's setting hammer to set the outside V-groove down. This locks the two V-grooves together. The other gores are assembled in the same manner. During assembly, the prick punch marks on each gore are aligned in a straight line so that the elbow will be aligned properly. When all gores are assembled and locked, the elbow should look like the one in step D of figure 73. The slip joint connection for gore I is made with a beading machine and a crimping machine and looks like the slip joints shown in figure 35.

7-36. *Turn vanes.* Seventeen turn vanes for joint 6 of trunk line A are to be made from the pattern shown in figure 69. After cutting out and slitting have been accomplished, each turn vane is bent to a radius of 2.8 inches with 1½-inch straight edges. Then the ¾" x 1.07" tabs are alternately bent 90° so that the turn vanes can be fastened inside the duct joint somewhat like the splitters shown in figure 40. Each turn vane is riveted or spot welded to the top and bottom of joint 6.

7-37. *Flexible connection.* The 24" x 14" x 6" flexible connection used in trunk line A is shown with detail views in figure 56. The patterns for the asbestos cloth and metal connector pieces are shown in figure 74. Instructions for forming and assembly are included in this illustration. As you can see in step A, the asbestos cloth pattern is 77 inches long (including 1-inch seam allowance) and 6 inches wide. The pattern for the two metal connector strips has overall dimensions of 3½" x 77¼" which includes seam and S-and-drive connection allowances (step B). The ends of the pattern for the metal have Pittsburg seam allowances. One side has a ½-inch allowance for S-and-drive connections, and the other side has 1-inch allowance for the double seam. Notice the 45° and 90° notches which make it possible to make the corner bends after the double folded seams are made.

7-38. These metal patterns are small and do not require stiffening along cross brake lines. Therefore, the first forming step is to make the pocket for the Pittsburg lock seam. Next, the cornice brake is used to make the 90° flange for the Pittsburg seam and the 180° bend to start the double seam. This double seam is started, as shown in step C of figure 74, by bending the outside ½-inch strip 180° along its 76-inch length. Next, the long side of the cloth is inserted into the 180° fold, and the metal is flattened with the cornice brake. In step D of figure 74, the cornice brake is used to make another fold and to flatten the metal to secure the cloth with a double seam. The same steps are repeated to attach the other metal connector strip. Both connectors are attached with double seams, as shown in step D of figure 74. The next step is to use the cornice brake to make the corner bends (along the element lines) and the ¼-inch flange for the Pittsburg seam. Since the asbestos cloth and both connector strips are attached (step E), the cornice brake will make the 90° bends across all three pieces. Next, the Pittsburg seams are assembled and locked on both of the metal connector pieces. The last step is to use a shop-made hand folder (fig. 71) to make the 180° folds for the drive slip connections. This completes the forming and assembly of the flexi-

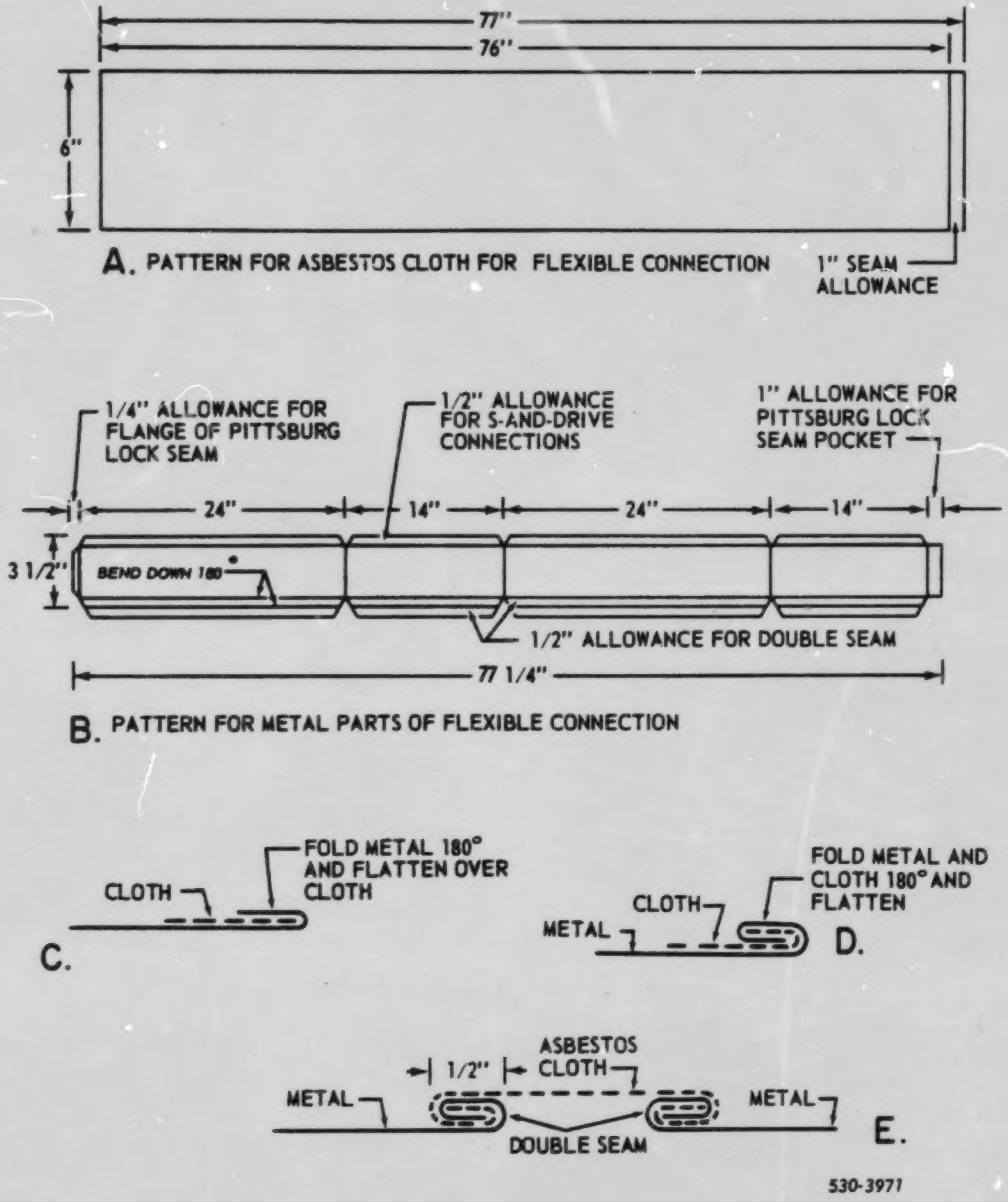

77"
76"
6"
A. PATTERN FOR ASBESTOS CLOTH FOR FLEXIBLE CONNECTION
1" SEAM ALLOWANCE
1/4" ALLOWANCE FOR FLANGE OF PITTSBURG LOCK SEAM
1/2" ALLOWANCE FOR S-AND-DRIVE CONNECTIONS
1" ALLOWANCE FOR PITTSBURG LOCK SEAM POCKET
24"
14"
24"
14"
3 1/2"
BEND DOWN 180°
1/2" ALLOWANCE FOR DOUBLE SEAM
77 1/4"
B. PATTERN FOR METAL PARTS OF FLEXIBLE CONNECTION
CLOTH
FOLD METAL 180° AND FLATTEN OVER CLOTH
C.
CLOTH
METAL
FOLD METAL AND CLOTH 180° AND FLATTEN
D.
1/2"
ASBESTOS CLOTH
METAL
METAL
DOUBLE SEAM
E.
530-3971

Figure 74. Flexible connection—patterns and assembly.

ble connections, which should now look like the drawing in figure 56.

8. Installation of Duct System Components

8-1. After duct system components are fabricated, they are taken to the designated site and installed in a building. The installation procedures include locating centerlines for routing of the duct; hanging and joining duct joints; insulating; and installing registers, grilles, and diffusers. Now let's see how the duct system components shown in foldout 1 are installed.

8-2. **Centerlines and Duct Routing.** Routing and the centerline of a duct system can be determined from the working drawings or blueprints of the system. The centerline is an imaginary line that passes through the middle of all the duct joints as the horizontal and vertical center. For example, if a chalk line is stretched (without sagging) through trunk line B from the center of the first 18" x 10" joint to the center of the end 12" x 8" joint, the chalk line will pass through the center of each joint and transition. This is possible because each transition is designed to maintain the same centerline (horizontal and vertical). The horizontal centerline can be determined from a plan view drawing, and the vertical centerline can be determined from an elevation view drawing.

8-3. In foldout 1 you can see that the horizontal centerline of trunk lines B and C is halfway between the walls of the hallway. If you take a rule or an architect's scale, you will find the centerline to be 22 inches from each side of the hall. Later when you are hanging and aligning joints in the building, you will use a chalk line (or chalk marks) to locate the horizontal centerline in the attic of the building. If the building in foldout 1 has a pitched roof with the ridge running parallel to the length of the building, a plumb line can be used to locate the horizontal centerline because the centerline of trunk lines B and C will be directly below the ridge.

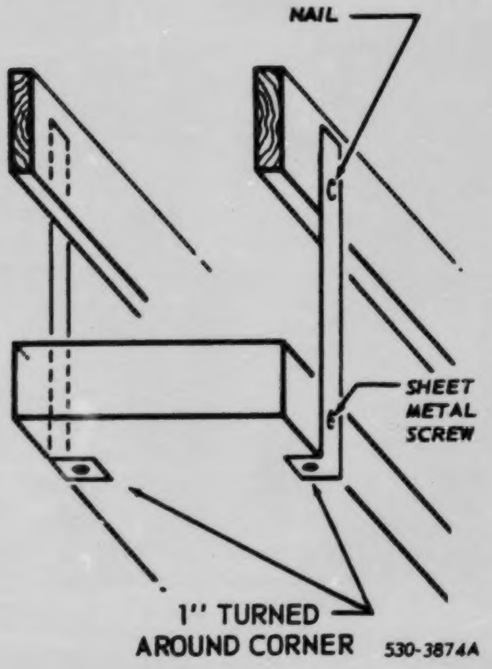


Figure 75. Strap hangers.

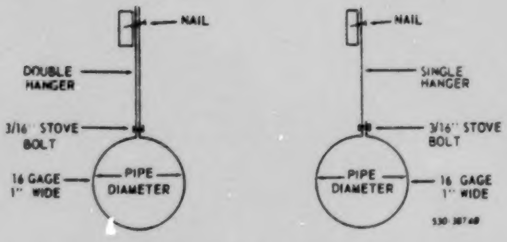


Figure 76. Hangers for round duct.

8-4. You can determine the vertical centerline of the duct system by using the elevation view in foldout 2, where the centerline of trunk line A is 20 inches above the ceiling. This vertical centerline is also shown in figure 61. This illustration shows the centerline through the round duct; notice that it is also 20 inches above the ceiling. In this system all of the duct joints are installed with their centerlines 20 inches above the ceiling; however, in some situations, you may find duct systems that have vertical centerlines that change. In either case, the working drawings or blueprints will include the information you need to locate the vertical centerlines.

8-5. **Hangers.** In Volume 2 of this course, you learned that hangers are used to support and level heating and air-conditioning ducts. The size and shape of the hangers are determined by the size, weight, and material of the duct and by the characteristics of the structure to support the duct. Hangers made of angle iron are used for heavy duct joints that require extra support. The duct joints on foldout 1 are supported with strap hangers made of 16-gage sheet metal cut in 1-inch strips or lighter gages (such as 24-gage) cut in 2-inch strips and folded like a drive slip to make double thickness 1-inch strips. These hangers are nailed at one end to the rafters or other structures in the attic, as shown in figure 75. Notice how the ends of the hangers are turned around the lower corners of the duct and secured with sheet metal screws. A Whitney punch is used to make the holes in the hangers. A portable electric drill is used to make the holes of the duct for the sheet metal screws. Two kinds of hangers for round duct are shown in figure 76. These hangers are made of 16-gage material 1-inch wide or double thickness of lighter gage materials. Notice how each hanger loops around the pipe and is fastened with stove bolts instead of sheet metal screws. One type shown in the illustration has a single strap that is nailed to a rafter; and the other type has a double strap, also nailed to a rafter.

8-6. **Planning for the Installation.** Most of the planning and scheduling for installation of a duct system is done by the superintendent and shop supervisors; however, you will be responsible for taking the needed tools, equipment, and materials to the job site. It is important that you have everything needed at the job site to eliminate lag time which can be caused by extra trips back to the shop. The duct system shown in foldout 1 is mostly in the attic of the building and, if possible, should be installed before the ceiling is covered. The duct joints can be hung and aligned more rapidly and safely if you are standing on scaffolds than if you are working in the attic. Some of the items that should be taken to the job site to install this duct system include the following:

Tool kits (one per man)
1/4" portable electric drills and twist drills
Electrical extension cords of sufficient length
Whitney hand punches
Chalk lines and chalk
Scaffolds or ladders
Fabricated duct joints for the job
S-and-drive slips
Hangers
Sheet metal screws, nails, and stove bolts
Insulation and fasteners

8-7. **Installing Duct Joints.** In the previous discussions of the duct system shown in foldout 1, we have described layout; fabrication; centerlines; duct routing; and the necessary tools, equipment, and materials needed at the job site. Now let's continue and see how the duct joints are installed. If the heating and cooling unit is already installed when you get to the job, the plenum should be installed first. If the heating and cooling unit is not yet installed, the first joint to be installed is the flexible connection (joint 3) of trunk line A. Remember that in this example the rectangular joints are connected with S-and-drive slips, the round duct joints are connected with slip joint connections, the rectangular takeoff fittings are connected with tapped connections, and the round duct takeoff fittings are connected with dovetail seams.

8-8. The supply plenum, as you can see in foldout 2, rests on top of the cooling coils. The coils are in a housing that has a 1-inch turned-up flange which the 24" x 24" plenum fits over. Sheet metal screws are used to fasten the plenum to the flange. Before the plenum top cover is installed, the takeoff fitting (joint 2 in fig. 53) should be installed. (This takeoff fitting is usually installed at the sheet metal shop before delivery to the job site.) The plenum has a 14" x 24" side opening to which the takeoff fitting is attached. The tabs along the top and bottom edges of this takeoff fitting are bent the same as those shown in figure 29; however, the sides are not bent because when this takeoff fitting was fabricated, the sides were formed slightly different from a regular tapped connection. These sides are S-shaped to fit over the plenum like S-slips. When the takeoff fitting is installed on the plenum, this S-connection makes a tight fit for the sides, and the tabs along the top and bottom hold the fitting to the plenum. The takeoff fitting does not need to be supported with hangers because it is firmly attached to the plenum.

8-9. The flexible connector (joint 3) is attached to the takeoff fitting and to joint 4 with S-and-drive slips, as shown in figure 27. It is a good idea to install hangers on the joint 4 side of the flexible connector to prevent tearing of the asbestos cloth when joint 4 is connected. Alignment of trunk line A begins with these first two hangers, which must be installed so that duct will be on the centerlines.

8-10. Joints 4 and 5 can be connected with S-and-drive slips before hanging and connecting to the flexible connection. Remember, you have a vertical and a horizontal centerline to maintain. A chalk line can be used to locate the horizontal centerline of trunk line A, which will be easy to follow, as you install each joint so that the points of intersection of the cross brake lines are directly over the chalk line. The hangers should be suspended from the rafters so that the vertical centerline of the duct will be 20 inches above the ceiling. The first hangers in figure 53 are attached to the joint 4 end of joint 3. The remaining hangers should be installed on 48-inch centers (or less). When securing the hangers to the duct with sheet metal screws, be sure to punch (or drill) holes in the hangers so that they are larger than the screws.

8-11. The remaining rectangular joints of trunk lines A, B, and C are joined, aligned, and hung in the same manner as explained for joints 4 and 5. However, joint 6 of trunk line A should have the turn vanes and the two takeoff fittings installed prior to hanging. The top for the plenum and the ends of the three trunk lines are installed as shown in figure 67.

8-12. The branch lines are installed after the trunk lines. This is begun by attaching the round takeoff fittings to the trunk lines by bending the tabs of the dovetail seams. The other joints of the branch lines are hung by connecting the slip joints and fastening with three sheet metal screws at each joint connection; these joints are supported on 48-inch centers (or less). The branch lines continue on the centerlines that are 14 inches above the ceiling joists and follow the horizontal centerlines (chalk lines). Figure 61 shows a 6-inch branch line with the centerline 20 inches above the ceiling.

8-13. If the ceiling has not been installed, the ends of the drop joints should be placed so that they will be flush with the ceiling when it is installed. If the ceiling has already been installed, a hole should be cut and the drop joint installed with a flush fit. In either case, the outlets should be in the location designated by the working drawing or blueprint.

8-14. **Installing Insulation.** After the duct joints have been hung and connected, the next step is to wrap the joints with insulation. For this job, use 1-inch foil-backed glass fiber insulation, in 100-foot rolls 4 feet wide. Some sheet metalworkers prefer a shop-made knife for cutting insulation. They take an old hacksaw blade, wrap the handle with tape or make a wooden handle, and sharpen the edge on the grinder. When installing insulation, you will find that a three-man crew can work efficiently: one man cutting the insulation and two men wrapping it around the duct.

8-15. A piece of insulation 48" x 102" is cut and wrapped around the plenum. This allows 6 inches for the seam. The 3 inches on each end are turned up 90° somewhat like a standing seam then folded over until the folds lie flat against the plenum. When completed, this folded seam resembles a grooved seam and extends 12 inches above the top edge of the plenum cover. A piece of insulation 28" x 28" is cut to cover the plenum top, and the edges are rolled up somewhat like a corner double seam. The final step for the plenum is to tie the 20-gage wire around the plenum near the top and near the bottom. The ends of the wire are twisted together and bent flat so that they will not pierce the insulation.

8-16. The joints of trunk line A are wrapped with pieces of insulation 48" x 82". The first piece butts against the plenum and covers all of joints 2 and 3 and most of 4 (fig. 53). It will be necessary to slit the material to fit around the hangers. The folded seam is made from the 6 inches of material allowed for the seam. The next piece of 48" x 82" insulation is wrapped around joints 4 and 5 and joins the first piece, edge to edge. The edges of the material have foil tabs that make light-fitting lap joints. When all of trunk line A is wrapped, wire is wound around each joint. Joint 6 of trunk line A will require some cutting so that the blanket will fit tightly around the two takeoff fittings for trunk lines B and C. The end of joint 6 is covered just like the plenum top.

8-17. When wrapping insulation, do not make it too tight because the material insulates better if not compressed. Also, if wrapped too tightly, the standing edges of the S-slips will punch through the foil and insulation. Be sure to cover the entire surface of the duct; any exposed portion will be subject to condensation when the air-conditioning system is in operation. Irregularities in the duct, such as transitions, can be wrapped by shaping the foil-backed insulation to fit the joint, then folding the excess material. The foil makes the insulation easy to form, since it will retain almost any desired shape.

8-18. The remaining trunk lines and branch lines are insulated in the same manner as trunk line A, except for the dimensions of the insulation pieces; the 12" x 8" sections of trunk lines B and C can each be wrapped with one long piece. Insulation for the elbows must be carefully applied because of the 90° turn. If the insulation is cut to cover only the elbow, it can be creased across the throat radius to make a good wrap. The insulation around the straight joints can lap the elbow insulation to make a good fit. Wire is used to secure the blanket where the pieces join.

8-19. **Installing Registers, Grilles, and Diffusers.** The final steps of a duct installation job are to install the registers, grilles, and diffusers. Installation of these items may occur later than the hanging of the joints; they are not installed until after the painting and wall finishing is completed. Registers, grilles, and diffusers are usually purchased factory made and unpainted. Since they may need painting to match the color of the walls, you should make arrangements with the paint shop to do this before installation time. If the items are spray-painted in the paint shop, they will have a better appearance than if painted at the job site. Coordination with the carpenters will insure that openings are made the correct size and at the correct locations.

8-20. *Installing registers.* The duct system we have been describing has one register, which is the 18" x 36" return air register shown in the return air duct (return air and outside air plenum) of foldout 2. This return air register differs from the supply register with adjustable louvers, which is shown in figure 49. The 18" x 36" return air register (FO2) has fixed louvers very much like those of return air grilles. (You will find that return air registers with fixed louvers are also called return air grilles by some manufacturers.) The return air register to be installed in the return air duct has fixed louvers with 35° down deflection, from the front side, it looks like view B of figure 50, but the louvers are flat instead of V-shaped. The face frame has screw holes and is installed with screws that attach to the wood frame which is a part of the wall. Because of this wood frame, it is not necessary for the end of the duct to have 90° flanges.

8-21. *Installing grilles.* Grilles are installed as explained in Chapter 2 and figure 50 of this text. However, the explanation did not include how you are to determine the location of the holes for the grilles. Location information is usually given on the working drawings or blueprints and will show the vertical and horizontal location. In some cases, you may need to make minor changes in the location of door grilles if panel doors are used instead of hollow core doors. In panel doors the opening for the grille should be made in the panel nearest the floor rather than the usual 6 inches above the bottom of the door. If the grilles are to match the color of the rooms, they should be sent to the paint shop prior to installation. When installing grilles in metal doors, the procedure is the same as that shown in figure 50 except that sheet metal screws are used.

8-22. The return air grilles for the walls in rooms 2, 3, 5, 6, 9, 10, 11, and 12 in foldout 1 will be boxed in (framed) by the carpenters and are located at floor level between the wall studs, which are on 16-inch centers. Screws will be used to install the front and back frames, as shown in figure 50. Installation of the door grilles in rooms 1, 7, 8, 13, and latrine will be essentially the same as shown in figure 50. The door grilles will be installed 6 inches above the bottom of the hollow core doors.

8-23. *Installing diffusers.* Figure 48 shows a typical diffuser and damper assembly used at the supply outlets of round ducts. These are factory made units and should be painted to match the room prior to installation. You will find installation easy if the round duct ends are flush with the ceiling. As with registers and grilles, installing diffusers is one of the last jobs during installation of a complete duct system. Fit the damper assembly (B, fig. 48) into the round duct and mark the location of the screw holes. After the holes are drilled in the round duct, the damper assembly is attached with sheet metal screws. Next, the diffuser (C, fig. 48) is attached to the damper assembly with countersunk oval-head sheet metal screws that come with the units. After tightening the screws, adjust the damper blades to the approximate position shown in figure 48. The diffusers in foldout 1 are like the one shown in figure 48, except that some are for 6-inch duct and some are for 8-inch duct.

9. Repair of Duct System Components

9-1. You will find that very little repair is required for most duct systems. Some duct systems have been in buildings for many years and are just as good as they were when installed. However, there are occasions when portions of ducts may need to be repaired or replaced. An air-conditioning duct that has the insulation removed or torn may have joints that have holes caused by condensation and rust. The exhaust duct system in the plating shop may require repair or replacement because of the corrosive action of the acid fumes. A portion of a building damaged by fire may need duct repair or partial replacement. Other repair jobs may be as simple as covering (patching) a hole in a duct.

9-2. **Patching.** Patching is usually done on small repair jobs which do not require replacement of whole joints or sections of a duct. For example, suppose you are to cover a hole in a 26-gage duct joint where a 6-inch branch line has been removed. A patch made from 26-gage metal (same kind as the duct) can be made to cover the hole. The patch must be large enough to cover the hole plus the amount needed for the seam. From your study of Chapter 1, you determined that a riveted lap seam is satisfactory to fasten the patch over the hole. You should remember that when using rivets with lap seams, the allowance is ¼ inch from the center of the rivets to each edge of the metal. Therefore, for a ¼-inch lap seam, you will need ½-inch allowance on the circular (disc) patch. The rivet holes should be ¼ inch from the outside edge of the patch, and spaced 2 inches apart. If a square or rectangular patch is needed to cover a square or rectangular hole, the allowance and rivet spacing is the same as for round patches. When heavier gages of metal are used, the lap seam allowance should be in accordance with Chapter 1 and the rivet spacing and size should be in accordance with volume 2 of this course.

9-3. In the preceding example, access to both sides of the hole is necessary for the patch to be attached with rivets. If the duct is assembled and you cannot reach behind the hole with a hand dolly, it will be necessary to attach the patch with sheet metal screws. Using sheet metal screws will not change the requirements for the size of the patch or the spacing of the holes; however, the holes punched in the patch must be larger than the screws. These holes in the patch can be used to locate and mark the spots to be drilled in the duct for the screw holes. The size of the sheet metal screws and holes can be determined from charts, such as those discussed in Volume 2.

9-4. **Replacement.** When damage to a duct is too extensive to repair with a patch, it may be necessary to fabricate a duplicate component and replace the old one with a new one. In the following paragraphs we will explain replacement of a flexible connection and a duct joint.

9-5. *Flexible connection replacement.* Flexible connections, such as that shown in figure 56, need to be replaced more often than metal duct joints because they are made of fabric and are subjected to vibration from the blower assemblies. When it is necessary to replace a flexible connection, examine the old connection and determine its dimensions, type of fabric, and type and gage of metal. After you have obtained this information, make a sketch of the component and make the patterns similar to those shown in figure 74.

9-6. As an example, assume that you are to replace a flexible connection. During examination of the old connection you determine that it is in a duct 16 inches high and 20 inches wide. The flexible connection is made of 12-ounce waterproof canvas, and the metal is 24-gage galvanized sheet iron. The canvas portion of the connection is 3 inches wide, and each metal strip is 3½ inches wide. From this information, draw a sketch of the assembly. If you have bulk rools of preassembled flexible connection material, it is necessary to determine the stretchout distance, add the allowance for the Pittsburg lock seam, and cut off the required amount, which in this example is 73¼ inches. Since preassembled flexible connection material has the canvas already attached to the metal strips, the remaining steps include notching, as shown in figure 74; making the corner bends, drive slip bends, and Pittsburg lock seam bends, and assembling the Pittsburg lock seam.

9-7. If you do not have preassembled flexible connection material in bulk rolls, it will be necessary to use the sketch and dimensions you have made from the old connection, prepare a pattern, as shown in figure 74, and make up the whole connection as explained for joint 3 of trunk line A earlier in this chapter.

9-8. After the replacement flexible connection is made, return to the building where the replacement is to be installed and remove the old connection. This is done by straightening and removing the drive slips that hold the flexible connection. With the drive slips removed, the old flexible connection can be removed by pulling the metal strips out of the S-slips on the top and bottom of the connection. It is a good idea to make new drive slips because the old ones are usually damaged during the removal.

9-9. When completed, the replacement flexible connection will look similar to figure 56; it is installed in the duct by inserting the S-slip allowances into the S-slips of the other joints. Next, the drive slips are fitted to the side pieces and then locked by bending the ends around the corners of the duct.

9-10. *Duct joint replacement.* The same general procedure applies to the replacement of any duct joint. Examine the joint to be replaced; make a sketch of the joint; and note the dimensions, type of metal, and gage of metal. For example, figure 77 illustrates a duct, including takeoff joint 12, which is to be duplicated.

9-11. After making the sketch, draw horizontal centerlines on the original joint and then make similar centerlines on the sketch. From these centerlines you can doublecheck all of the dimensions. Notice that joint 12 reduces from a 36" x 12" trunk line to one 12" x 12" trunk line and two 12" x 12" branch lines. The two branches are called takeoffs, which are efficient ways of dividing airflow without the need for deflecting dampers or turn vanes. You will encounter variations of this type of takeoff in many duct systems.

9-12. Using the sketch and dimensions shown in figure 77, it is not difficult to lay out patterns to make a duplicate of the joint. Figure 78 shows the patterns you should make for the top, bottom, and sides. Notice how the horizontal centerlines can be used to doublecheck the dimensions. The beginning point for making pattern A is the 36-inch straight line across the large end. Divide this line into three 12-inch parts, and draw two perpendiculars 18 inches long and two 42 inches long. The vertical centerline is perpendicular to the midpoint of the base line. The horizontal centerline is perpendicular to the vertical centerline at a point 18 inches from the base line. Next, 18 inches from the base line draw a line parallel to the base line and locate the vertex points for the 12-inch throat radius and 24-inch heel radius. From these vertex points, use a compass or scribe to make the heel and throat radiuses for the 90° takeoffs. The allowances include ½ inch at each end for the S-slip connections and ¼ inch on all sides for the flange of the Pittsburg lock seam. The outside lines of pattern A will be cut as indicated with unishears or hand snips. These patterns will require two pieces of 24-gage galvanized sheet iron.

9-13. The patterns for the side and heel and for the side and throat shown in figure 78 are simple rectangular patterns with the allowances and bend instructions added. Notice where pattern B is to be bent. These patterns also have ½-inch allowance for the drive slips and 1-inch allowance for the pockets of the Pittsburg lock seams. Patterns B and C will require four pieces of 24-gage sheet iron. These patterns can be cut with squaring shears and notched with straight snips.

9-14. Tools needed for bending and forming the patterns shown in figure 78 include a cornice brake, burring machine, slip roll machine, Pittsburg lock forming machine, mallet, and hand dolly. Starting with patterns for the top and bottom, the ¼-inch flanges must be turned up on the bottom pattern and turned down for the top pattern. The burring machine is used to turn the flanges on the radius bends, and a mallet and cornice brake are used to turn the flanges on the straight edges. The flanges in the "V" of each takeoff must be turned with the mallet and hand dolly because the burring machine will not go all the way.

9-15. The pockets for the Pittsburg seams on the side, heel, and throat patterns are made on the Pittsburg lock forming machine; then curved portions are formed into a 12-inch radius with the slip roll forming machine. When adjusting the gripping rolls, leave them loose enough so as to not damage the pockets of the Pittsburg lock seams. As the last step, use the cornice brake to make the 160° bend in the heel pattern and the 180° bends for the drive slip connections. The standing S-slips from the old joint can be reused; however, it is desirable to make new drive slips for all connections.

9-16. To disassemble the duct so that the old joint can be removed, it is necessary to release the joint connections. Make certain that the duct is supported before taking off the drive slips. Notice in figure 77 that this duct is supported by hangers attached to joints 11 and 13, with none attached to joint 12. In this example it is desirable to first remove joints 14 and 15 to make the removal and installation of the damaged joint easier. Begin by taking off the registers and any fasteners that attach joints 14 and 15 to the walls, then remove the drive slips and pull each joint through the holes in the walls. With joints 14 and 15 out of the way, the drive slips can be removed from both ends of joint 12. Up to this point no trouble should be encountered; however, slipping joint 12 sideways

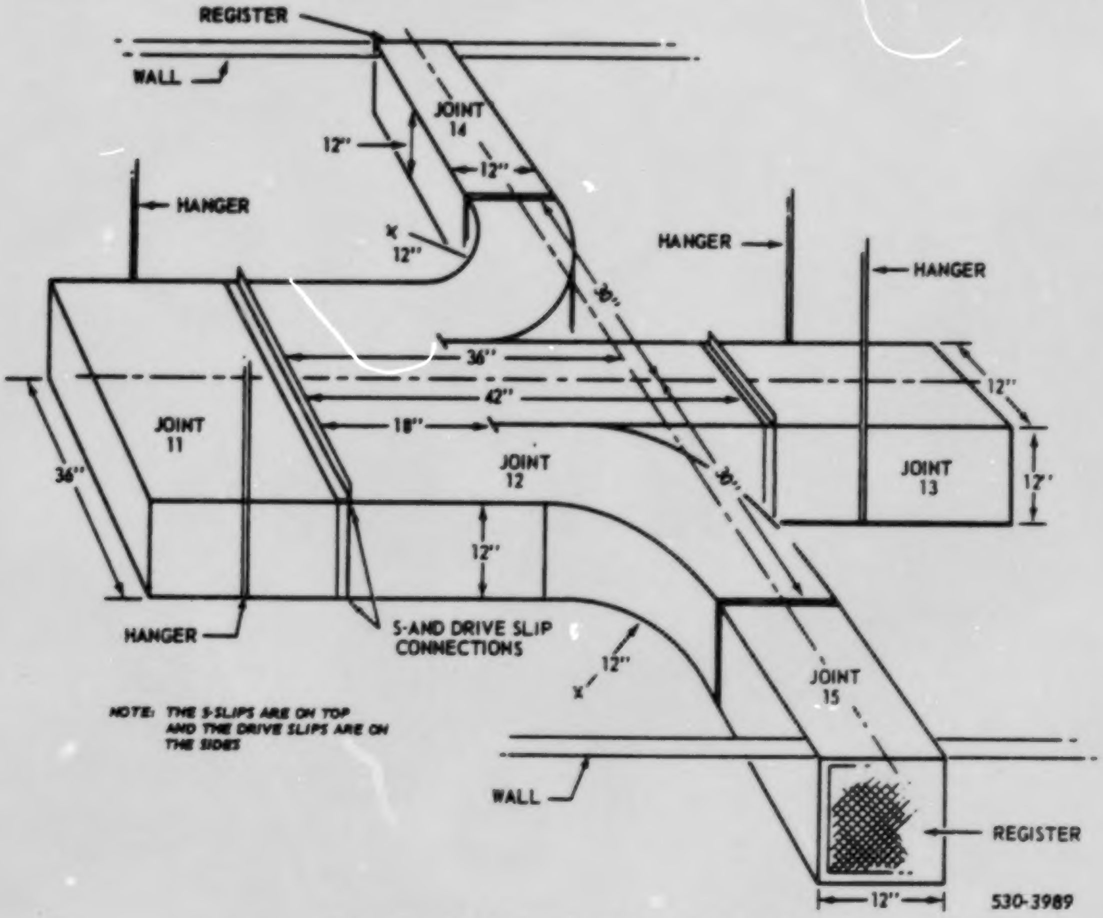

REGISTER
WALL
JOINT 14
12"
12"
HANGER
X
12"
HANGER
HANGER
36"
42"
18"
12"
JOINT 11
36"
JOINT 12
JOINT 13
12"
12"
HANGER
S-AND DRIVE SLIP CONNECTIONS
12"
X
JOINT 15
NOTE: THE S-SLIPS ARE ON TOP AND THE DRIVE SLIPS ARE ON THE SIDES
WALL
REGISTER
12"
530-3989

Figure 77. Sketch of a takeoff joint to be replaced.

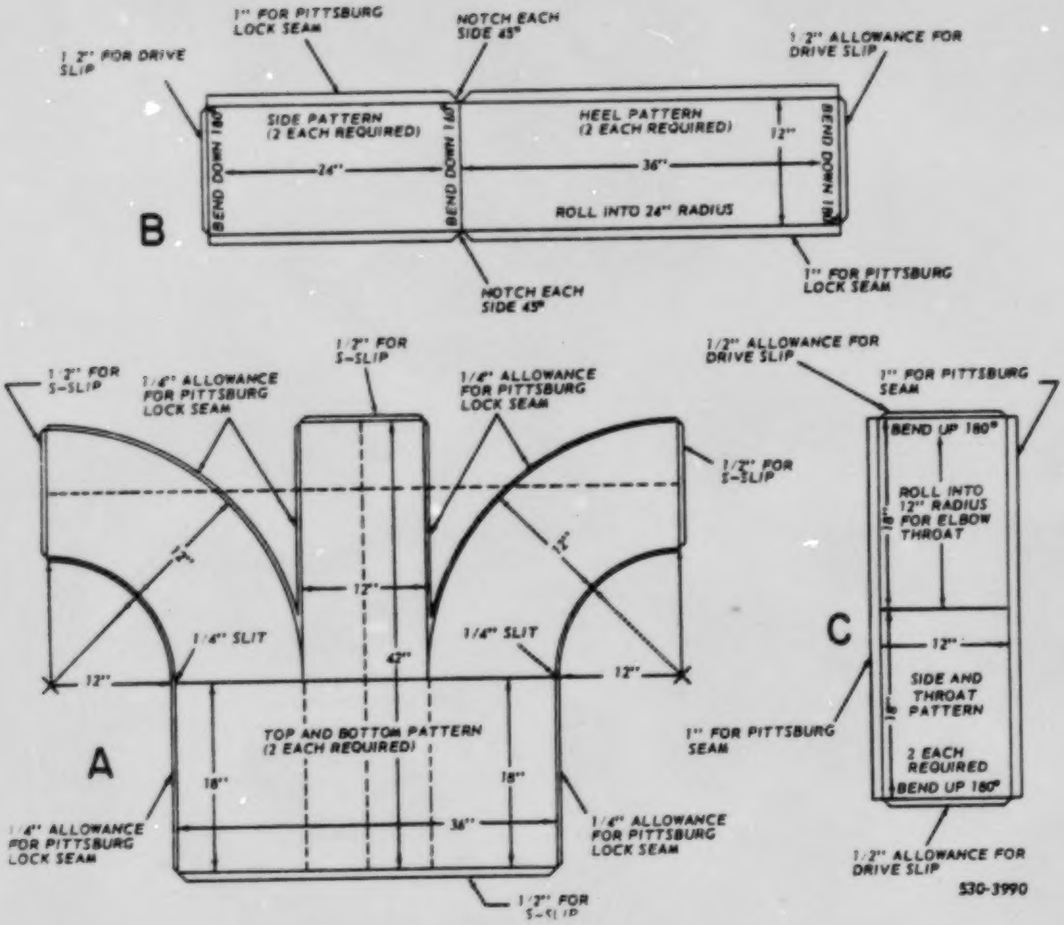

1" FOR PITTSBURG LOCK SEAM
NOTCH EACH SIDE 45°
1/2" ALLOWANCE FOR DRIVE SLIP
1/2" FOR DRIVE SLIP
SIDE PATTERN (2 EACH REQUIRED)
HEEL PATTERN (2 EACH REQUIRED)
BEND DOWN 180°
24"
36"
12"
ROLL INTO 24" RADIUS
B
NOTCH EACH SIDE 45°
1" FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
12"
1/4" SLIT
42"
1/4" SLIT
TOP AND BOTTOM PATTERN (2 EACH REQUIRED)
A
18"
18"
36"
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
1/2" ALLOWANCE FOR DRIVE SLIP
1" FOR PITTSBURG SEAM
BEND UP 180°
ROLL INTO 12" RADIUS FOR ELBOW THROAT
C
SIDE AND THROAT PATTERN
2 EACH REQUIRED
BEND UP 180°
1" FOR PITTSBURG SEAM
1/2" ALLOWANCE FOR DRIVE SLIP
530-3990

Figure 78. Patterns for replacement takeoff joint 12.

out of the duct may present some problems unless joints 11 and 13 can be moved apart. Joints 11 and 13 must be moved back at least 1 inch so that the overlapping metal of the S-slip allowances will clear each end of joint 12. If a flexible connection is in the trunk line, the duct can be pushed in that direction. If a flexible connection is not close enough, some other method must be used. It may be possible to push back joints 11 and 13 enough to make a 1-inch opening; however, if this is not possible, you may have to use aviation snips and make slits so that the sides can be bent back to allow the lapped edges to clear. If this latter method is used, it will be necessary to make some modifications when installing the replacement joint.

9-17. Installing the replacement for joint 12 is not difficult if joints 11 and 13 were spread enough to slide joint 12 out of the S-slips; however, if cutting was necessary, installation of the new joint will require some extra steps. One way to get enough room to slide joint 12 into place is to turn the bottom S-slip around so that the ½-inch allowances at the top and bottom will fit outside the other joint instead of inside-outside, as shown in figure 27. It is necessary to do this at each end of joint 12. Another way to install joint 12 is to cut off the ½-inch S-slip allowances between joints 11 and 12 and between joints 12 and 13. To do this, you make butt joints instead of lap joints and make new standing S-slips from heavier gage (22-gage) metal with 2-inch pockets instead of 1-inch pockets. When the new joint is in place, install the drive slips but do not bend the ends down just yet. Joints 14 and 15 are replaced and connected with the old S-slips and the new drive slips; then the registers are reinstalled. The last step is to bend the ends of each drive slip to lock them in place.

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Fabrication, Installation, and Repair of Stacks and Ventilators

THIS CHAPTER DEALS with the fabrication, installation, and repair of stacks and ventilators as well as the effect of wind on their efficiency. Stacks are used to exhaust heated gases from stoves, furnaces, and hot water heaters; and ventilators are used to remove hot air and to exhaust harmful or unpleasant fumes.

2. You will repair and replace stacks and ventilators more frequently than duct system components because they are installed on the outside of buildings and are exposed to moisture, temperature changes, and wind. In addition to the corrosion and damage from the weather, stacks and ventilators are subject to deterioration from heat, moisture, and corrosive vapors which they exhaust.

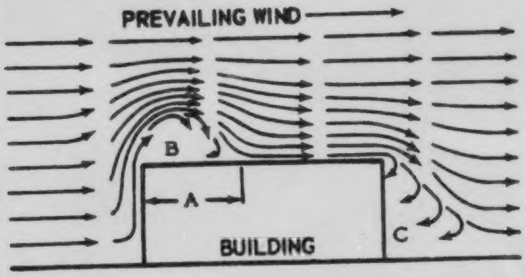
3. The knowledge and skills you have already gained will be useful when working with stacks and ventilators because the layout, fabrication, and assembly are similar to those of other round duct components. The main exception is that additional fire precautions must be taken with stacks that carry heated gases from stoves and furnaces.

10. Effect of Wind on Stacks and Ventilators

10-1. Stacks and roof ventilators should be located above the roofs of buildings so that the natural updraft will receive maximum assistance from the suction areas caused by the wind. Natural updraft is a characteristic that makes heated air (gases) flow upward through a stack or ventilator when the inside temperature is higher than the outside temperature. Thus, heated air from a furnace will flow through a vertical stack because the temperature at the top of the stack is lower. The same principle applies to a ventilator, although the temperature difference is not as great. Wind is also a natural force and is used to assist or increase the natural updraft; however, the effect varies from time to time because of the variation in the direction and velocity of the wind.

10-2. Figure 79 shows the airflow over a building. The area of greatest suction on top of the building is identified by the letter B, which is located near the upwind edge where the wind is forced upward. If possible, the outlet of a stack or ventilator should be located in this suction area. At the end of area A in figure 79, the wind is flowing downward and will tend to flow into a stack or ventilator located there. To prevent this unfavorable condition, the stack should be located in a more favorable position or raised to a point where the wind flows straight across the opening. A stack or ventilator located at point B will have the greatest suction from the wind. Second best is any location where the wind is flowing straight across the roof. The least desirable location is at the end of area A, where the air is turbulent and flowing downward. In all cases, the opening of the stack or ventilator should be above the highest part of the roof in order to take advantage of the wind from any direction. The downwind side of a building (C, fig. 79) is also a low-pressure area. The upwind side is a high-pressure area.

10-3. The location and height of ventilators are available on heating and ventilation blueprints or working drawings. For example, foldout 1 in this text shows the location of the furnace flue (stack), and foldout 2 shows the height and details of construction. Notice that the flue is 30 inches high. Normally, it will not be your responsibility to determine the location or height of stacks and ventilators; but since you will be replacing them from time to time, the replacements should have the correct height. Usually, the size of the replacement will be the same as the original; however, if you suspect the old one is not correct, consult your supervisor before making the replacement.



530-3972

Figure 79. Airflow over a building.

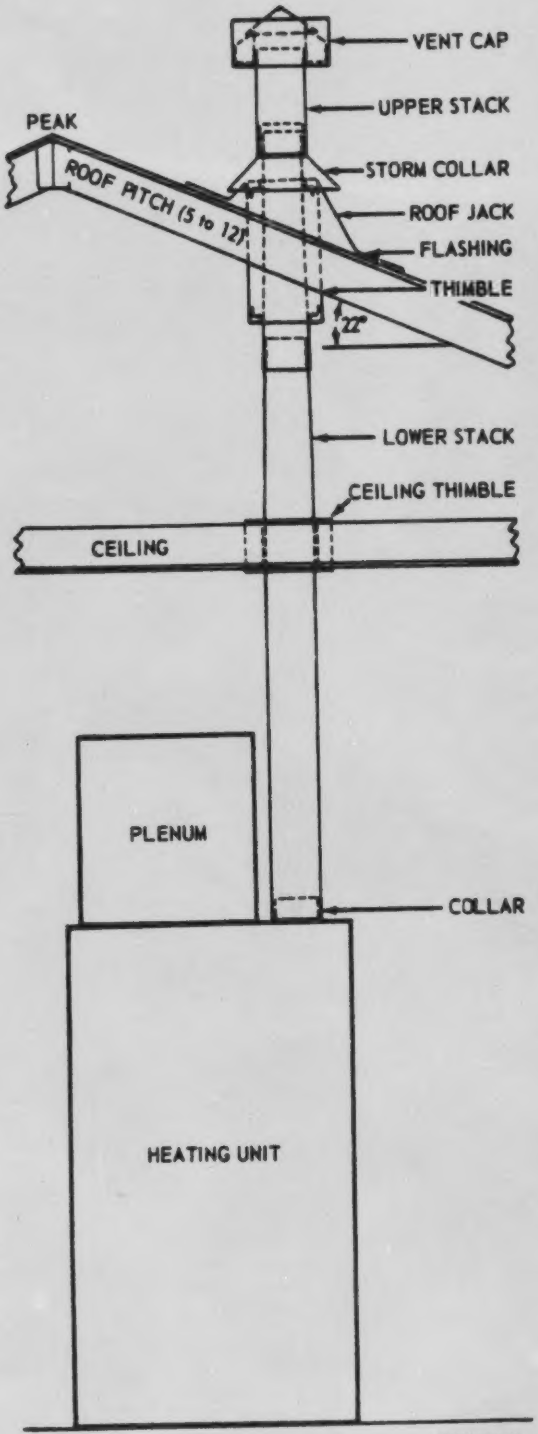
11. Stacks and Associated Components

11-1. Stacks are sometimes called by other names, such as heating vents, vertical flues, and chimneys. In this text, we use the term "stacks" to describe sheet metal round duct (pipe) used to exhaust hot gases from stoves, furnaces, and hot water heaters. By *associated components*, we mean items used with stacks, such as draft diverters, thimbles, roof jacks, storm collars, and vent caps. Figure 80 shows a typical stack and its associated components. Notice the names of the components: vent cap, upper stack, storm collar, roof jack thimble, flashing, lower stack, and ceiling thimble.

11-2. **Single-Wall Stacks.** Single-wall stacks, as the name suggests, are stacks with only one wall. The single-wall stack shown in figure 80 has joints of round pipe, such as those shown in figure 35. Fabrication of the joints of single wall stacks is the same as described in Chapters 1 and 3. Fabrication of the associated components will be discussed later in this chapter. Joints of the single-wall stack are available in shapes such as straight pipe, elbows, and tee joints.

11-3. **Double-Wall Stacks.** Double-wall stacks (pipe) consist of one single-wall joint installed inside another with approximately ½ inch of airspace between. This airspace, which you can see at the ends of several joints shown in figure 81, acts as insulation and prevents the outer wall from overheating. The inner wall is usually made of aluminum, and the outer wall may be made of aluminum or galvanized iron. Double-wall stacks are used to vent gas-fired heaters, furnaces, and water heaters. The aluminum inner wall resists corrosion, and the airspace prevents condensation; therefore, double-wall stacks have a longer life than stacks of single-wall construction.

11-4. Double-wall stacks can be fabricated in the shop but are usually purchased as factory-made items. In figure 81 you can see that a



530-3987

Figure 80. Single-wall stack and associated components.

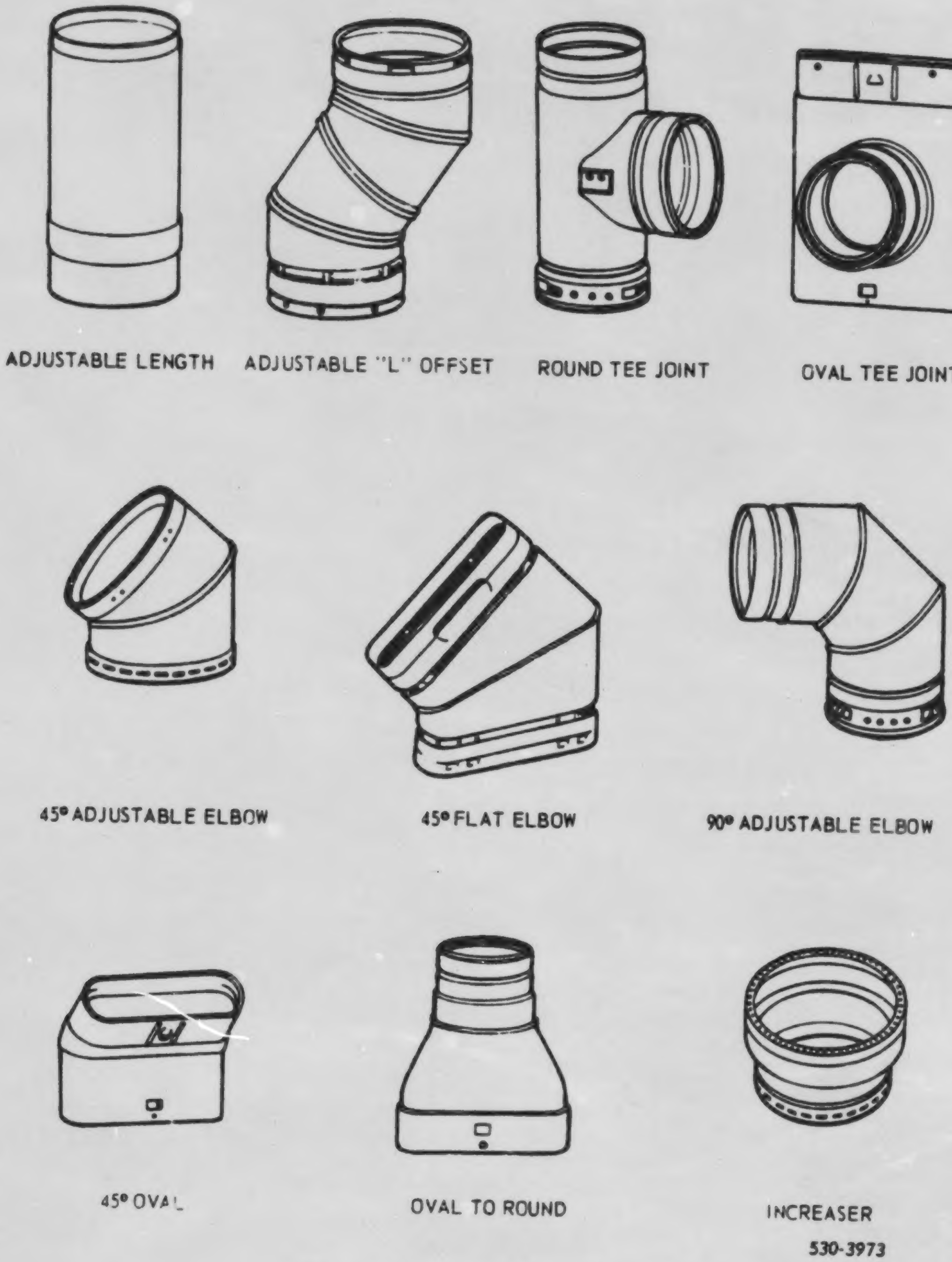

ADJUSTABLE LENGTH
ADJUSTABLE "L" OFFSET
ROUND TEE JOINT
OVAL TEE JOINT
45° ADJUSTABLE ELBOW
45° FLAT ELBOW
90° ADJUSTABLE ELBOW
45° OVAL
OVAL TO ROUND
INCREASER
530-3973

Figure 81. Double-wall stack components.

locking slip joint is used instead of the conventional crimped slip joint that is used with single-wall pipe. Most manufacturers have their own patented type of joint connection for double wall pipe. It is important, when ordering double-wall pipe, to order the appropriate type so that the joints can be connected.

11-5. Joints of double-wall stacks (pipe) can be purchased in various shapes, diameters, and lengths. Some of the shapes of round and oval joints are shown in figure 81. These are available in various sizes. The round joints are available with diameters (of the inside pipe) from 3 to 12 inches and with lengths from 6 to 60 inches.

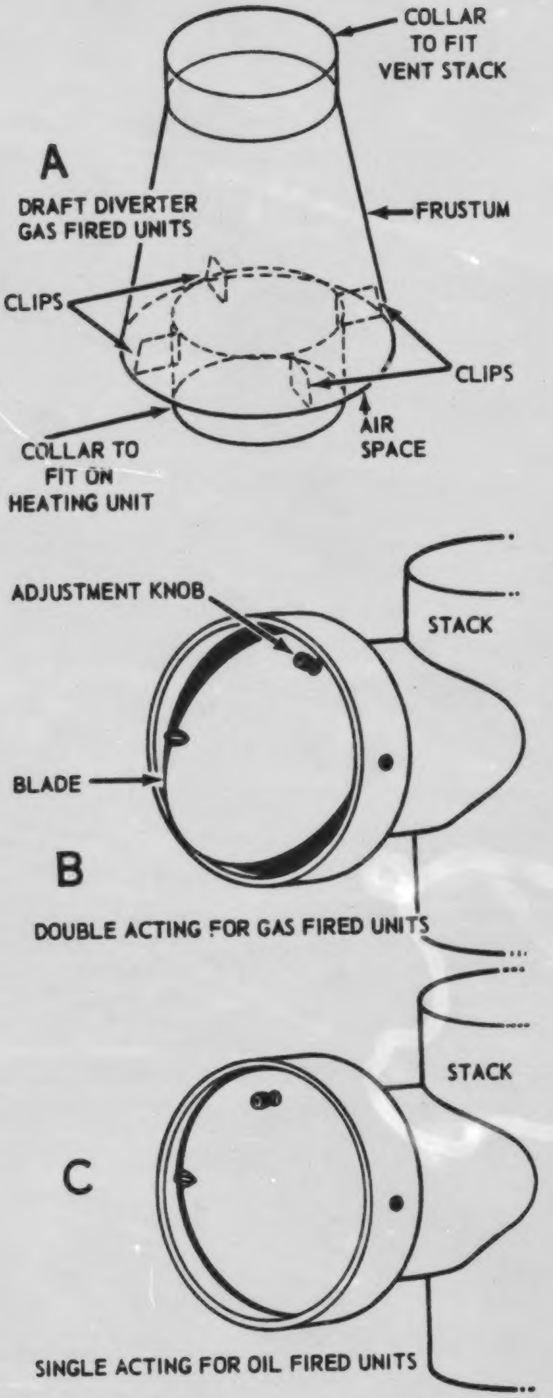

COLLAR TO FIT VENT STACK
A
DRAFT DIVERTER GAS FIRED UNITS
FRUSTUM
CLIPS
CLIPS
AIR SPACE
COLLAR TO FIT ON HEATING UNIT
ADJUSTMENT KNOB
STACK
BLADE
B
DOUBLE ACTING FOR GAS FIRED UNITS
STACK
C
SINGLE ACTING FOR OIL FIRED UNITS
530-3974

Figure 82. Three types of draft diverters.

For in-between lengths, the adjustable-length straight joint is used. It is similar to the ordinary straight joint and is made in two sections that telescope to make any combination of length. The tee joint in figure 81 is a straight joint with a branch attached.

11-6. **Draft Diverters.** Draft diverters are used with vent stacks for heaters and furnaces and are available in various sizes and types. These devices prevent excessive updrafts or downdrafts in the vent stacks. The draft diverter shown in view A of figure 82 has no movable parts and consists of the frustum of a cone with collars attached at each end to act as slip joint connections. The clips center the bottom of the cone so that there will be an equal airspace all around the lower collar. The lower collar is the same size as the vent outlet on the heating unit and is installed as the first joint in a stack. The upper collar is the same size as the stack.

11-7. The double-acting draft diverter shown in view B of figure 82 is another type of damper used for gas fired furnaces. It is installed horizontally as a tee—off one of the joints of a stack close to the heating unit. Notice that it has a hinge which allows the blade to swing in to dampen updrafts and to swing out to dampen downdrafts. The blade has an adjustable knob that is used to balance the blade; therefore, the hinge on the blade should always be installed parallel to the floor.

11-8. The single-acting draft diverter shown in view C of figure 82 is used for oil fired furnaces. The blade on this type swings inward only. This draft diverter is also installed horizontally to the floor as a tee—off a horizontal or vertical joint of a stack close to the heating unit. The single-acting and double-acting draft diverters are used with stacks that are 7 to 10 inches in diameter.

11-9. **Wall Thimbles.** Wall thimbles provide a safety feature for the stack assembly. They are constructed in such a way that air can circulate between the stack and the wall. The wall thimble shown in figure 83 is fabricated in two parts, A and B, and is fastened together with threads during installation. View C of figure 83 shows how the thimble is screwed into the wall after a hole, the size of the thimble, is cut in the wall. The flange of the thimble provides a nice fit and acts as a stop when you screw the two parts of the thimble together. This type of wall thimble is adjustable to different wall thicknesses and therefore can be used to accommodate a variety of installation.

11-10. Another type of thimble that is commonly used is shown in figure 84; it is used in ceilings as well as in walls. This is a shop-made

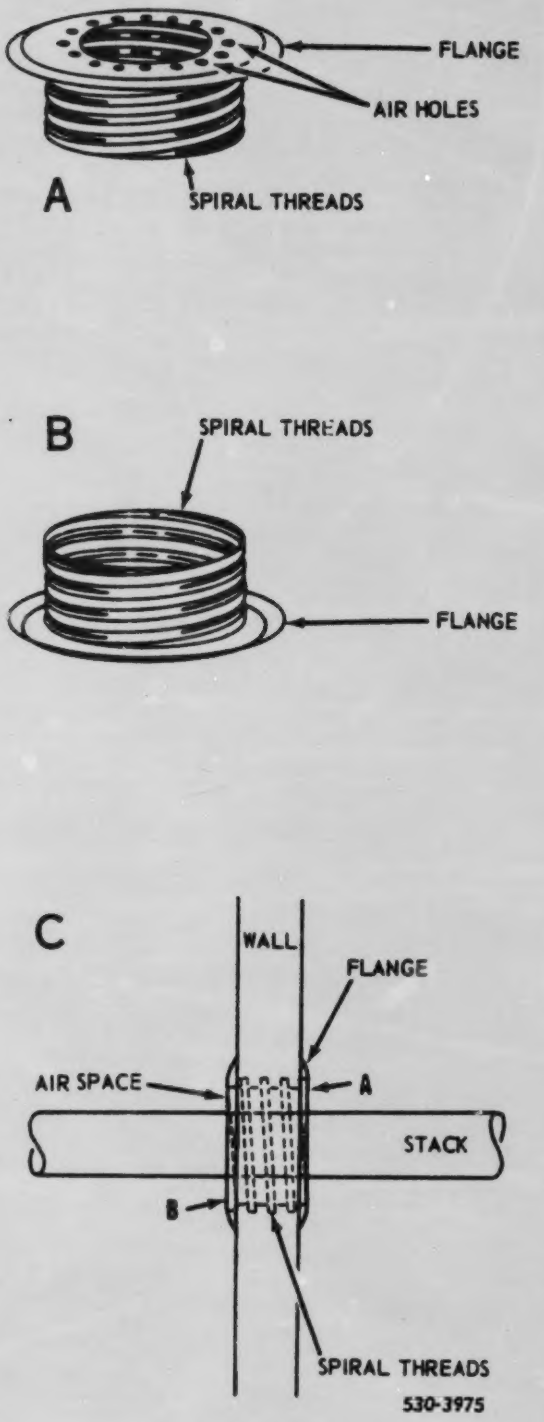

FLANGE
AIR HOLES
A
SPIRAL THREADS
B
SPIRAL THREADS
FLANGE
C
WALL
FLANGE
AIR SPACE
A
STACK
B
SPIRAL THREADS
530-3975

Figure 83. Wall or ceiling thimble.

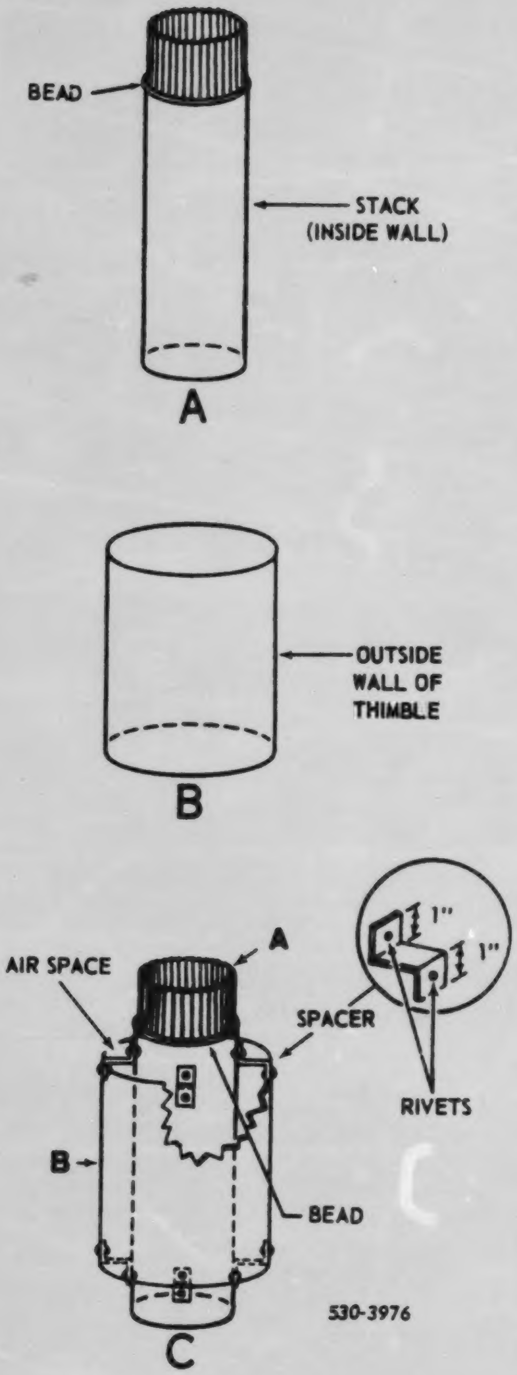

BEAD
STACK
(INSIDE WALL)
A
OUTSIDE
WALL OF
THIMBLE
B
AIR SPACE
A
1"
1"
SPACER
RIVETS
B
BEAD
C
530-3976

Figure 84. Shop-made double-wall thimble.

double-wall thimble. To fabricate this type of thimble, make a length of stack as shown in view A of figure 84; then make an outside piece, as shown in view B of figure 84, which is 4 inches shorter than the inside wall. This will accommodate the 1½-inch slip joints and allow a smooth joint connection. When thimble parts A and B are made, they are joined with the Z-clips, as shown in view C of figure 84. The Z-shaped clips are 1 inch wide and have 1-inch spaces on each end to which the inside and outside parts of the thimbles are riveted. Assembly of the thimble will be easier if you rivet the Z-clips to the outside piece first.

11-11. **Roof Jacks.** A roof jack, such as that shown in figure 85, is the part of a vent system which is attached to the roof to provide weatherproofing for the opening through which the stack passes. Roof jacks may be fabricated or purchased "ready made" for different sizes of vent stacks and different-pitch roofs. The roof jack in foldout 2 is for a flat roof. The dimensions for roof jacks are shown on the drawings, or if replacement is required, the dimensions can be taken from the old roof jack. As you can see in figure 85, the base of a roof jack acts as a flashing and is used to secure the jack to the roof deck.

11-12. **Storm Collars.** A storm collar is the part of a stack assembly which is used to prevent leaks around the top of a roof jack. Storm collars used on double-wall vent pipe are usually purchased as "readymade" items. However, storm collars for single-wall vent pipe are usually fabricated in the shop. To make a storm collar, you should obtain the correct dimensions from a drawing or the old collar. Using the proper dimensions make piece A, as shown in figure 85, with a slight taper so that the top stack will fit over it; then turn a flange about ⅜ inch wide on the bottom at the angle of the collar. Next, make piece B and then join A and B to make C (fig. 85). The joint is spot-welded, or riveted, and then soldered to prevent leakage.

11-13. Now, you can install the collar as shown in view D of figure 85. With the thimble installed on the roof jack, the top of the outside piece of the thimble should fit flush with the top of the roof jack. The storm collar should completely cover the top of the thimble opening to prevent rain from blowing in through the airspace. Looking again at view 4 of figure 85, you can see that the vent stack above the roof is installed through the storm collar with a tight fit to prevent rain from entering. All components are installed over each other to completely cover all seams in the assembly.

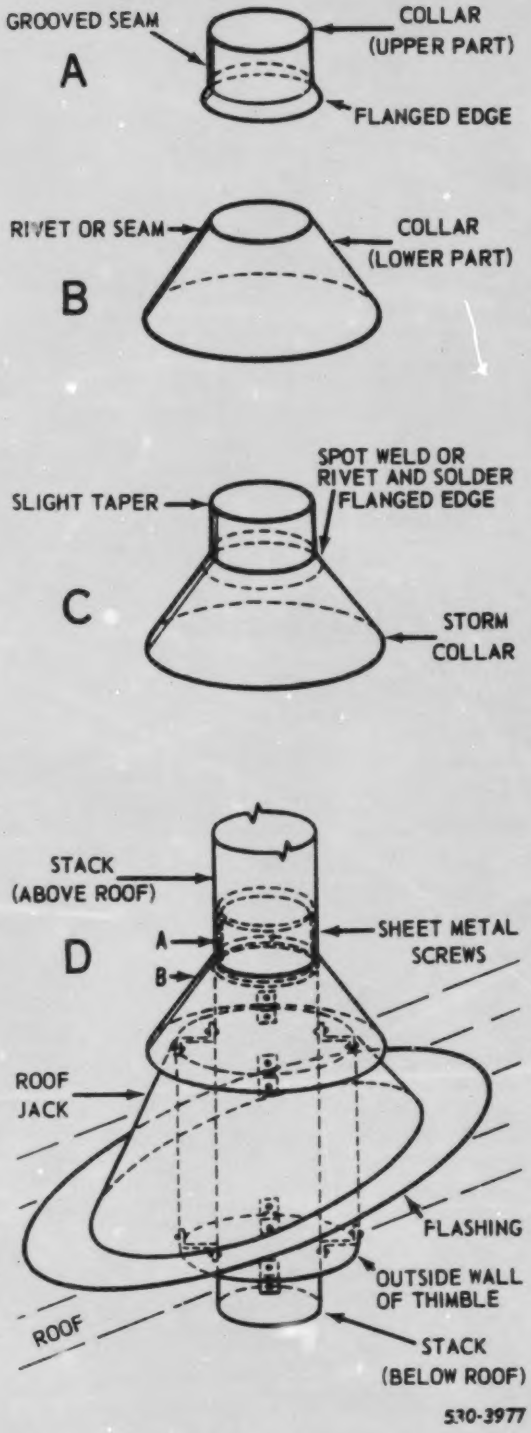
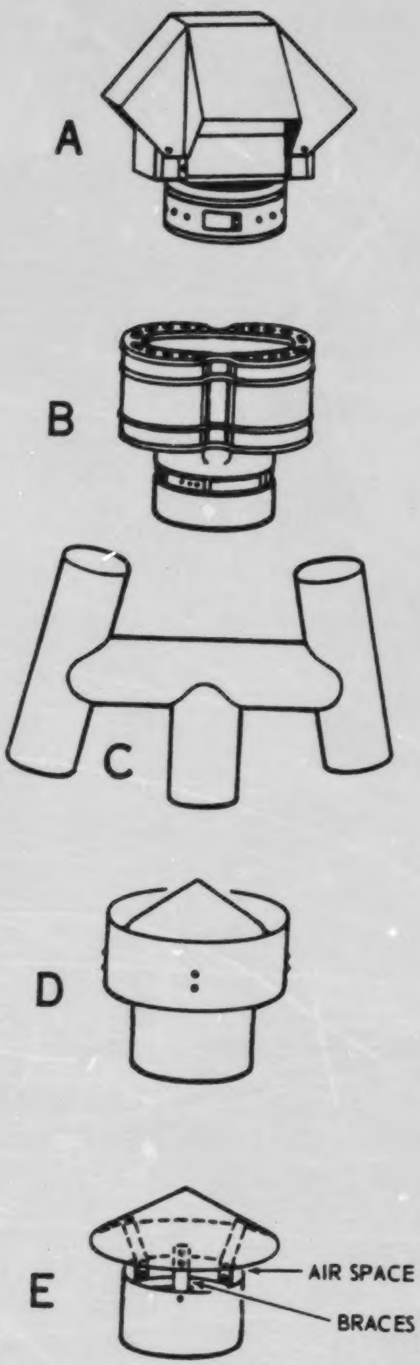


Figure 85. Storm collar, roof jack, and double-wall thimble.



530-3978

Figure 86. Vent caps.

11-14. **Vent Caps.** Vent caps are installed at the outlet end (top) of a stack vent. Several different types are used on heating equipment stacks, five of which are shown in figure 86. Vent caps A and B are usually purchased "ready-made" and are used with double wall stacks. Vent caps C, D, and E can be purchased or fabricated in the shop and are used with single-wall stacks. The vent cap illustrated in view A is often referred to as a Belmont cap. Vent cap C is better known as an A cap because of its shape. Vent cap E is sometimes called a china cap because of its shape and the opening all around the top. Vent caps B and D are called rainproof or draftproof caps.

11-15. The type of stack used for various installations is specified on the working drawing. In foldout 2, you will notice that a weatherproof downdraft diverter is specified. Therefore, a vent cap like the one shown in view D of figure 86 is required for the installation.

12. Repair, Fabrication, and Installation of Stacks and Associated Components

12-1. Stacks are subject to corrosion from heat, moisture, and fumes or from wind damage. Most of the repairs you will encounter will be the replacement of parts or the complete stack assembly. If a stack, collar, vent cap, or roof jack is corroded (rusted out), it needs to be replaced. Visual examination of the assembly will help you to determine which parts need replacement. If you find that a stack is badly corroded, probably the collar and vent cap are also defective. In any event, replace all damaged sections of the assembly. To fabricate a stack assembly (such as the one illustrated in foldout 2) or any of its components, make the patterns and cut, form, and assemble the pieces.

12-2. From the drawing in foldout 2, you can determine that double-wall aluminum vent pipe is specified for use from the furnace stack outlet to the top of the roof jack. The working drawing also specifies that 24-gage galvanized metal be used for the roof jack, upper stack, and vent cap. The thimble is made from 20-gage galvanized sheet metal. For repair jobs, the old assembly can be used to determine the metal thickness.

12-3. After you have determined the material specifications, you need to know the length and size of the double-wall stack. For this example, let's assume that the vent outlet on the heating unit is 6 inches in diameter and 6 feet from the top of the heater stack outlet to the top of the roof jack. With these requirements in mind, you can see that two 3-foot joints of 6-inch double wall stack should be purchased.

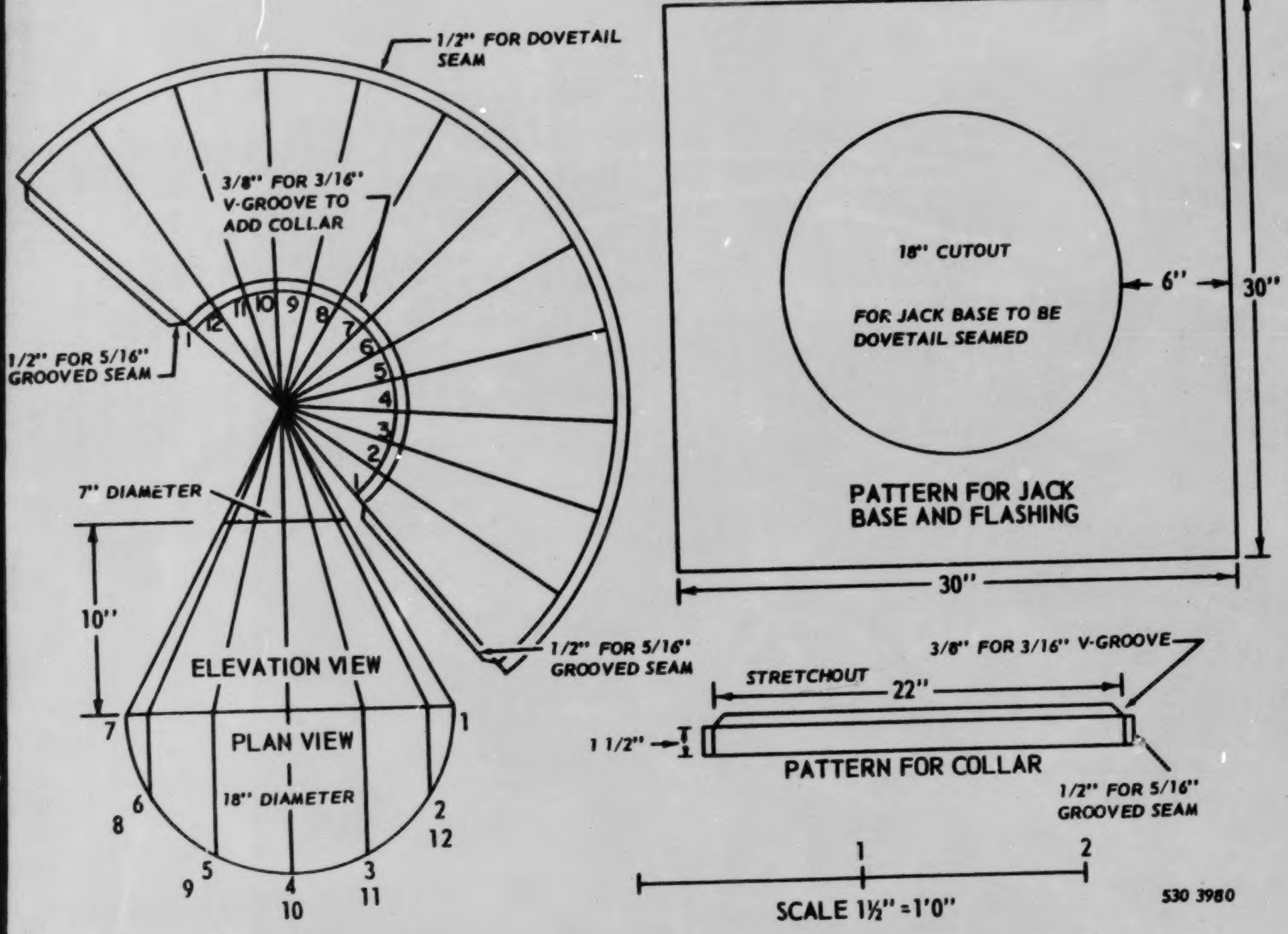

1/2" FOR DOVETAIL SEAM
3/8" FOR 3/16" V-GROOVE TO ADD COLLAR
1/2" FOR 5/16" GROOVED SEAM
1 12 11 10 9 8 7 6 5 4 3 2 1
7" DIAMETER
10"
ELEVATION VIEW
PLAN VIEW
18" DIAMETER
7 6 8 5 9 4 10 3 11 2 12 1
1/2" FOR 5/16" GROOVED SEAM
18" CUTOUT
FOR JACK BASE TO BE DOVETAIL SEAMED
6"
30"
PATTERN FOR JACK BASE AND FLASHING
30"
STRETCHOUT
22"
3/8" FOR 3/16" V-GROOVE
1 1/2"
PATTERN FOR COLLAR
1/2" FOR 5/16" GROOVED SEAM
1
2
SCALE 1½" =1'0"
530 3980

Figure 87. Patterns for a roof jack.

12-4. **Making Patterns for Stacks and Associated Components.** The vent stack shown in foldout 2 is to be fabricated and installed. The assembly is similar to the one shown in figure 80, except that a conical-shaped roof jack is required for the flat roof. The roof jack is 10 inches high, and 6-inch flashing is needed for the base; the sides of the roof jack are designed for a 60° angle.

12-5. *Pattern for a roof jack, base, and collar.* Patterns for the jack, base, and collar are illustrated in figure 87. The radial line layout method is used to develop the pattern for the roof jack (frustum). The diameter of the top opening is 7 inches, and the diameter of the base opening is 18 inches. The 7-inch top opening is necessary because the double wall vent stack is designed to include a ½-inch airspace. After pattern development, allowances for seams are made as shown in the illustration. The pattern for the roof jack base (flashing) is 30″ x 30″, with an 18-inch diameter cutout in the center. The collar for the top of the roof jack is ½″ x 22″ with allowances added.

12-6. *Pattern for a stack joint.* The next pattern for the vent assembly is the top stack joint shown in figures 80 and 88. This single-wall stack joint is 20 inches in length because the roof jack is 10 inches high, and a distance of 30 inches must be maintained from the bottom of the vent cap to the roof line. Remember to make the diameter 7 inches so that it will fit over the roof jack collar. The stretchout is 22 inches long and 20 inches high plus the allowances. The 1½ inch slip joint allowance is made for the connection with the vent cap.

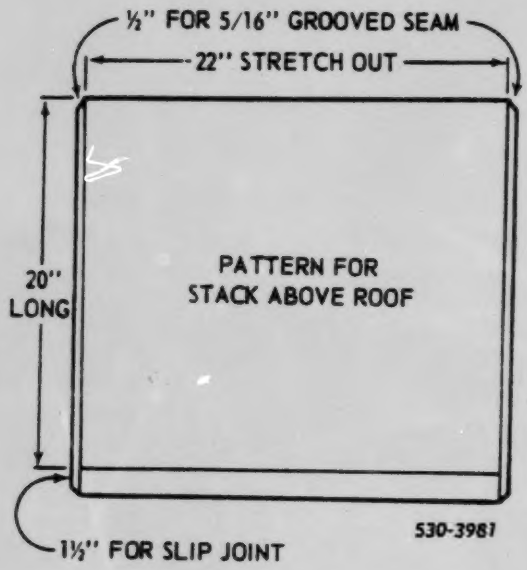


Figure 88. Pattern for a single wall stack joint.

12-7. *Pattern for a vent cap.* The next pattern of the stack assembly, shown in foldout 2 and figure 80, is the vent cap, which consists of several parts. The vent cap is a draftproof and weatherproof type with a top, ring, collar, and braces.

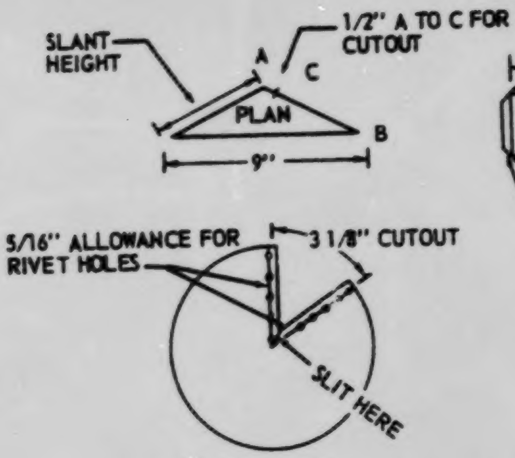
12-8. The cover (top) is the first pattern of the vent cap, as shown in view A of figure 89. To lay out the cover, draw an elevation view 9 inches in diameter and 2 inches high. Notice on the elevation view that you have a slant height which is represented by line AB. Set a pair of dividers equal to the distance of line AB and draw a circle. This is the beginning of the pattern for the vent cap cover. To obtain the dimensions for the cutout, set the dividers equal to the distance of ½ the cap diameter (from elevation view). Next, use point B as a radius point and strike an arc on line AB to form line CB. Measure the distance from point A to point C, which in this example is ½ inch. Now multiply ½″ x 6.28 (2π) to obtain the length of the arc for the cutout. In this case, it is 3.14 inches (3⅛ inches). This distance is marked off on the pattern as shown, and the seam allowance is made. In this example, 5/16-inch allowance is required on each edge for the riveted lap seam. The same seam allowance is used for spot welding.

12-9. The next pattern for the vent cap is the ring shown in view B of figure 89. The ring is 5½ inches wide and 11 inches in diameter, so the stretchout is 5½″ x 34 9/16″. A seam allowance of ½ inch is made on each end of the stretchout for the grooved seam, and a ¼-inch hem allowance is made on the top and bottom.

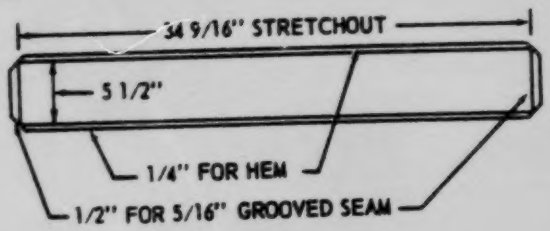
12-10. The next pattern to make is the collar, which is 4 inches high and 7 inches in diameter. The stretchout is 4″ x 22″, as shown in view C of figure 89. The grooved seam allowance of ½ inch at each end is made as shown in the example.

12-11. View D of figure 89 shows the brace pattern. The vent caps will need four braces made from 16-gage metal. Each brace is 1 inch wide and 9¾ inches in length. The braces hold the vent cap assembly together and are riveted to the top, collar, and ring.

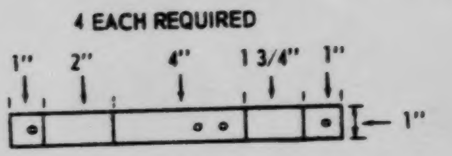
12-12. *Pattern for a ceiling thimble.* The ceiling thimble shown in foldout 2 and figure 80 should be purchased "readymade"; however, you may be required to make one. The ceiling thimble shown in the foldout permits the heating unit stack to run through the ceiling, as shown in figure 83. The same type of thimble can be



A PATTERN FOR TOP

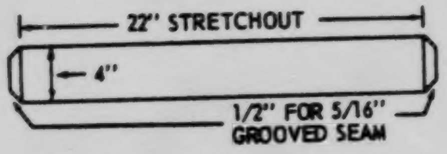


B PATTERN FOR RING



D PATTERN FOR BRACE

530-3982



C PATTERN FOR COLLAR

Figure 89. Patterns for a vent cap.

used to run a stack through a wall. Steps for fabrication of a ceiling thimble are shown in figure 90. To fabricate this type of thimble, make two rings, as shown in view A. The inside hole of the ring should be 7 1/16 inches in diameter so that a 7-inch diameter stack can pass through the opening. A 2-inch airspace is needed between the stack and sleeves, as shown in view D. A ½-inch flange must be added to the ring so that it will fit against the ceiling. Screw holes are punched in the ½-inch flange on ¼-inch centers from the outside edge and spaced 5⅝ inches apart (center to center). The 5/16-inch air holes are punched 2 1/16 inches apart (center to center).

12-13. Two sleeves for the thimble are made as shown in views B and D of figure 90. Notice that tabs are added to the outside sleeves only. The tabs are spot-welded or riveted to the sleeve and spaced to match the screw holes in the ring. The tabs are set back from the flange of the sleeve ⅝ inch or ½ inch, according to the thickness of the gypsum board used in the ceiling. The outside sleeve is made 1/16 inch larger in diameter than the inside sleeve so that the smaller of the two will slide inside the other. Both sleeves should be 6 inches in length. A ⅜-inch flange is turned on one end of each sleeve so that the flange can be spot welded to the ring. View C of figure 90 shows how the inside sleeve should look when completed. When installed, the ceiling thimble will look like view D of figure 90.

12-14. *Pattern for a vent stack brace.* The next part of the vent stack assembly is the brace, as shown in foldout 2 and figure 91. The brace is made in two pieces from ⅛" x 2" flat bar stock or 10-gage steel. The length of the brace should be 14½ inches if the rafters are located on 16-inch centers. Since the outside diameter of the stack is 7 inches, the brace is made in two half-round pieces, each with a 3½-inch radius. The brace is fastened to the rafters with ¼-inch stove bolts.

12-15. The pattern for piece 1 of the brace, as shown in view B of figure 91, is made on flat bar stock. A vise is used to make the 90° bends, and a slip roll machine is used to form the 11-inch half-round radius bend. A heavy-duty brace and wire bender, if available may be used to form the 90° bends. Piece 2 is formed

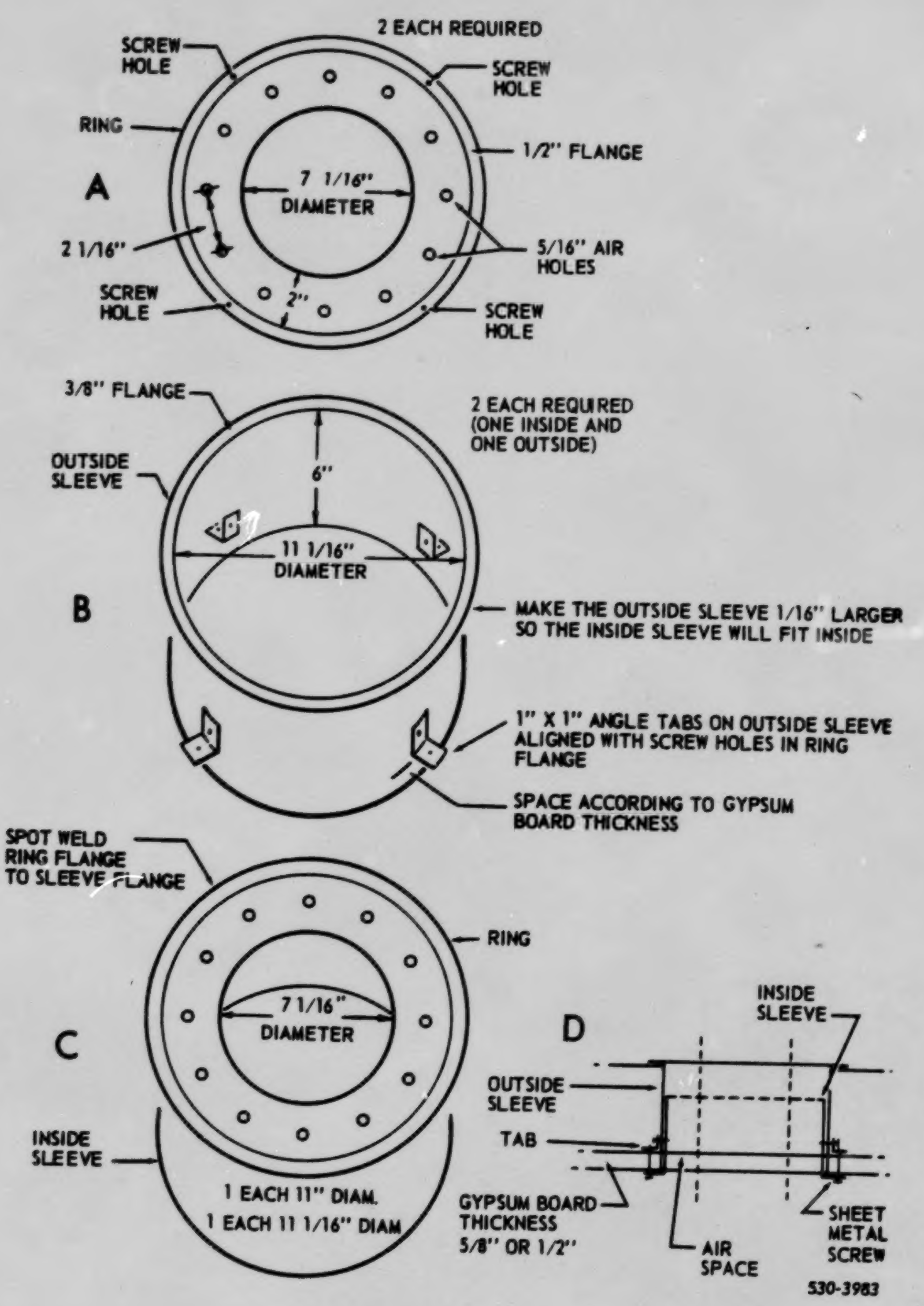

2 EACH REQUIRED
SCREW HOLE
SCREW HOLE
RING
1/2" FLANGE
A
7 1/16" DIAMETER
2 1/16"
5/16" AIR HOLES
SCREW HOLE
2"
SCREW HOLE
3/8" FLANGE
2 EACH REQUIRED (ONE INSIDE AND ONE OUTSIDE)
OUTSIDE SLEEVE
6"
11 1/16" DIAMETER
B
MAKE THE OUTSIDE SLEEVE 1/16" LARGER SO THE INSIDE SLEEVE WILL FIT INSIDE
1" X 1" ANGLE TABS ON OUTSIDE SLEEVE ALIGNED WITH SCREW HOLES IN RING FLANGE
SPACE ACCORDING TO GYPSUM BOARD THICKNESS
SPOT WELD RING FLANGE TO SLEEVE FLANGE
RING
7 1/16" DIAMETER
C
INSIDE SLEEVE
1 EACH 11" DIAM.
1 EACH 11 1/16" DIAM
D
INSIDE SLEEVE
OUTSIDE SLEEVE
TAB
GYPSUM BOARD THICKNESS 5/8" OR 1/2"
AIR SPACE
SHEET METAL SCREW
530-3983

Figure 90. Thimble fabrication.

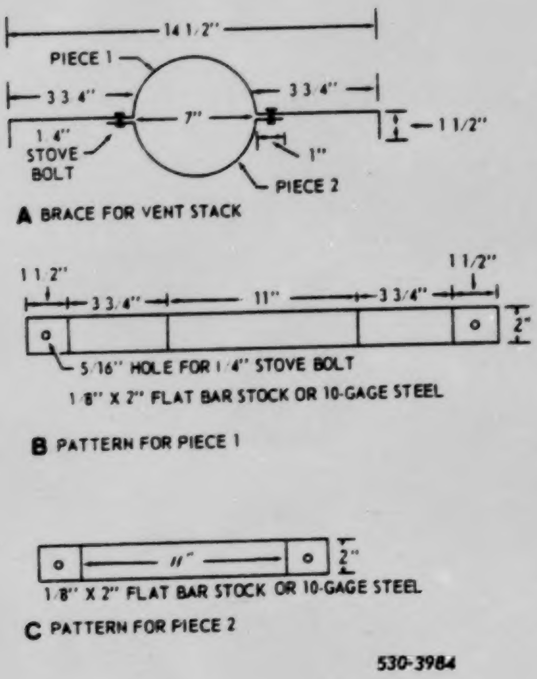


Figure 91. Making a brace for a vent stack.

the same way as piece 1; however, piece 2 does not require as many 90° bends. After the bending process is completed for both pieces, four 5/16-inch holes are drilled with a drill press.

12-16. **Cutting Patterns for Stacks and Associated Components.** Starting with the frustum pattern for the roof jack as shown in figure 87, the outside radius cut is made with straight-cut snips, the inside radius is cut with aviation snips, and the straight cuts are made with straight-cut snips. The pattern for the flashing and base is cut with ring and circle shears and squaring shears. The collar is cut with straight snips or squaring shears. All the notching is done with straight cut snips.

12-17. The pattern for the roof stack, shown in figure 88, is cut with squaring shears and notched with straight snips. All patterns in figure 89 are cut with squaring shears and notched with straight cut snips, except for the top pattern, which is cut with ring and circle shears or circle shears. The cutout is made with straight snips.

12-18. Patterns for the pieces shown in figure 90 are cut with ring and circle shears and squaring shears. The patterns illustrated in figure 91 do not require cutting, except for length, if 1/8" x 2" flat bar stock is used. If the bar stock is not available, power squaring shears should be used to cut the 10-gage metal.

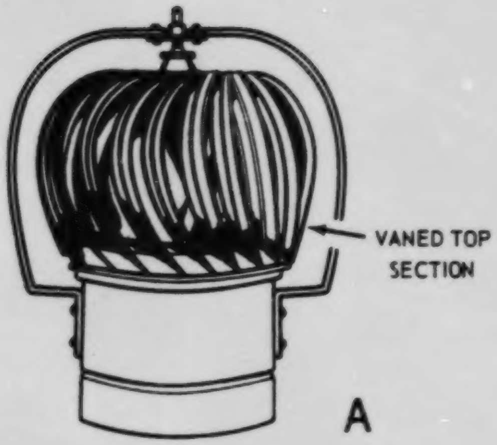
12-19. **Forming Patterns for Stacks and Associated Components.** The next step in the fabrication process is the forming of patterns. Patterns for the roof jack shown in figure 87 are formed on the bar folder, slip roll machine, hand groover, and elbow edging machine. When forming the frustum, the slip roll machine is set for a 7-inch circle on one end and for an 18-inch circle on the other end. The grooved seam edges for the frustum and collar are turned on the bar folder and formed with a hand groover on a bench stake. The V-groove is formed on the elbow edging machine and is used to join the frustum and collar. In forming the V-groove, remember that one component should have the V-groove inside and the other outside. We suggest that you make the inside V-groove on the collar.

12-20. Forming the roof stack, which is shown in figure 88, can be done with a Pittsburg lock forming machine and the slip roll machine. First, make the two pockets of the grooved seam (as shown in fig. 12) with the Pittsburg lock forming machine. Next, run the sheet through the slip roll machine to form the cylindrical shape. After forming, join the pockets and flatten the seam.

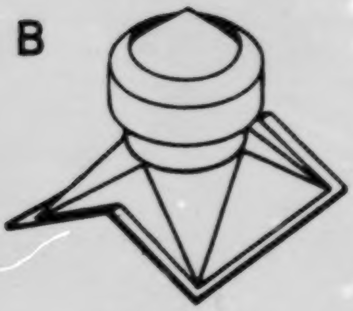
12-21. Forming the vent cap patterns shown in figure 89 is done with a cornice brake, Pittsburg lock forming machine bar folder, and the slip roll machine (except for the top pattern). The top pattern is formed on a blow horn stake by placing the center of the pattern on the point of the horn and lightly bending the top. For assembly, pull the pattern so that one allowance for the lap joint will slip over the top of the other allowance. The top can then be riveted on the blow horn stake.

12-22. The pattern for the ring (B in fig. 89) is hemmed on the bar folder, and the groove is formed on the Pittsburg lock forming machine. The pattern is then rolled into a cylinder on the slip roll machine. A bead 2 inches from the edge will stiffen the ring and help its appearance. The bead is made with a beading machine after the grooved seams are joined. Pattern C is formed the same as pattern B, except for the hems and bead. The brace (pattern D) is formed on the cornice brake by making two 90° bends, one 125° bend, and one 55° bend. The 90° bends are on the bottom of the brace, and the 125° and 55° bends are on the top of the brace.

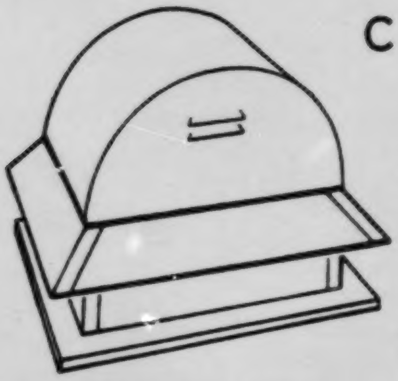
12-23. Forming the ceiling thimble patterns, as shown in figure 90, is done with the Pittsburg lock forming machine, slip roll forming machine, hollow mandrel stake, and burring machine. Two sleeves are required; they are formed by making the grooved seam on the Pittsburg machine, forming the cylinders on the slip roll machine,


VANED TOP SECTION
A

TURBINE VENTILATOR



DRAFT VENTILATOR



POWER VENTILATOR

530-3979

Figure 92. Ventilators.

locking the ground seam on the hollow mandrel stake with a mallet, and turning the ⅜-inch flange on the burring machine. The clips for the outside sleeve can be formed on the bar folder or the brace and wire bender.

12-24. **Assembly of Stack Components.** Next in the fabrication process is the assembly of the formed parts of the stack assembly. The roof jack, shown in figure 87, is joined to the base (flashing) with a dovetail seam. The ½-inch allowance on the frustum base is slit at ½-inch intervals to make ½" x ½" tabs, and every other tab is bent 90°. After joining, the remaining tabs are bent 90°. The dovetail seam is soldered to prevent leakage. The collar is installed at the top of the frustum by placing the V-grooves together. (You should recall how this was done earlier in this text during the assembly of elbow grooves.) The grooved seams should be soldered about 4 inches up the side to prevent leakage.

12-25. Assembly of the vent cap components, shown in figure 89, is done by riveting the top and collar to the braces. There are two rivets in the collar and one in the top of each brace. After the four braces are riveted, the ring is installed with sheet metal screws on each brace.

12-26. To assemble the ceiling thimble, illustrated in figure 90, the rings are spot-welded to the flanges of both sleeves. The 1" x 1" tabs are aligned with the screw holes in the ring ½ or ⅝ inch from the edge (according to the thickness of the gypsum board on the ceiling) and spot welded or riveted to the outside sleeve.

12-27. **Installation of Stack Components.** Installation of the stack components that are shown in foldout 2 is begun by locating center points where the stack will pass through the ceiling and roof. A plumb bob is used to locate the ceiling hole center point by suspending the plumb bob from the ceiling and aligning it with the center of the stack collar outlet on the heating unit. When the center is located, an 11⅛-inch hole is cut. The location of the roof jack is found by the same method as the ceiling outlet. The roof jack outlet should be cut 14½ inches in diameter. The roof jack is then set directly over the roof outlet and nailed to the roof. The jack is not installed until after a layer of roofing felt is installed.

12-28. When the roof jack is in place and the ceiling thimble is installed, the double-wall stack is placed over the collar outlet of the heating unit. The ceiling thimble is installed as shown in view D of figure 90. Install the inside sleeve in the ceiling outlet (11⅛-inch hole) from the bottom, and install the outside sleeve from the top. Align the outside sleeve tabs with the screw holes of the ring on the inside sleeve. Drill screw holes in the tabs so that sheet metal screws can be used to secure the thimble to the ceiling.

12-29. As the double-wall stack is installed through the thimble and into the roof jack, the joints are fastened together. The brace is then fastened to the stack and ceiling rafters as shown in foldout 2. The single-wall roof stack is installed through the roof jack and fastened with sheet metal screws. The last step is to fasten the vent cap to the roof stack with sheet metal screws. This completes the installation of the stack components.

13. Repair, Fabrication, and Installation of Ventilators

13-1. Ventilators are used to exhaust air from buildings either by gravity flow or by forced air. In figure 92 you can see three types of ventilators. View A shows a turbine (spin cat) ventilator. When the wind blows, the vaned top rotates, and the centrifugal action pulls air out of the building. The ventilator shown in view B operates like a stack, and the air removal depends on the wind and the temperature inside and outside the building. The ventilator illustrated is designed to be installed on the peak of the roof so that wind can blow across from any direction. The ventilator shown in view C has a motor-driven fan to pull the air out of the building and does not rely on the wind or temperature differences. There are design variations in all three types of ventilators shown in figure 92. Some ventilators, depending on the use and manufacturer, are used to exhaust air from range hoods, whereas others are used to exhaust attic heat from buildings. Attics with ventilators usually have louvers that allow the cooler outside air to enter the attic and then pass out through the ventilator. The louvers are usually located so that the face is toward the wind. This increases the airflow into the louvers and out through the roof ventilators.

13-2. Most ventilators have dampers to regulate the airflow. In the summer the dampers are usually left open, and in the winter they are opened or closed as required. Most power-operated ventilators, such as the one shown in view C of figure 92, have automatic louvers that open or close when the motor is turned on or off. This controls the backdraft in the system.

13-3. The repair of ventilators is similar to that of other sheet metal components—according to the damage. When ventilators are damaged by wind, hail, or corrosion, inspect the bad parts and determine whether the unit should be repaired or replaced. It may be possible to repair the damage with a simple patch. However, if the

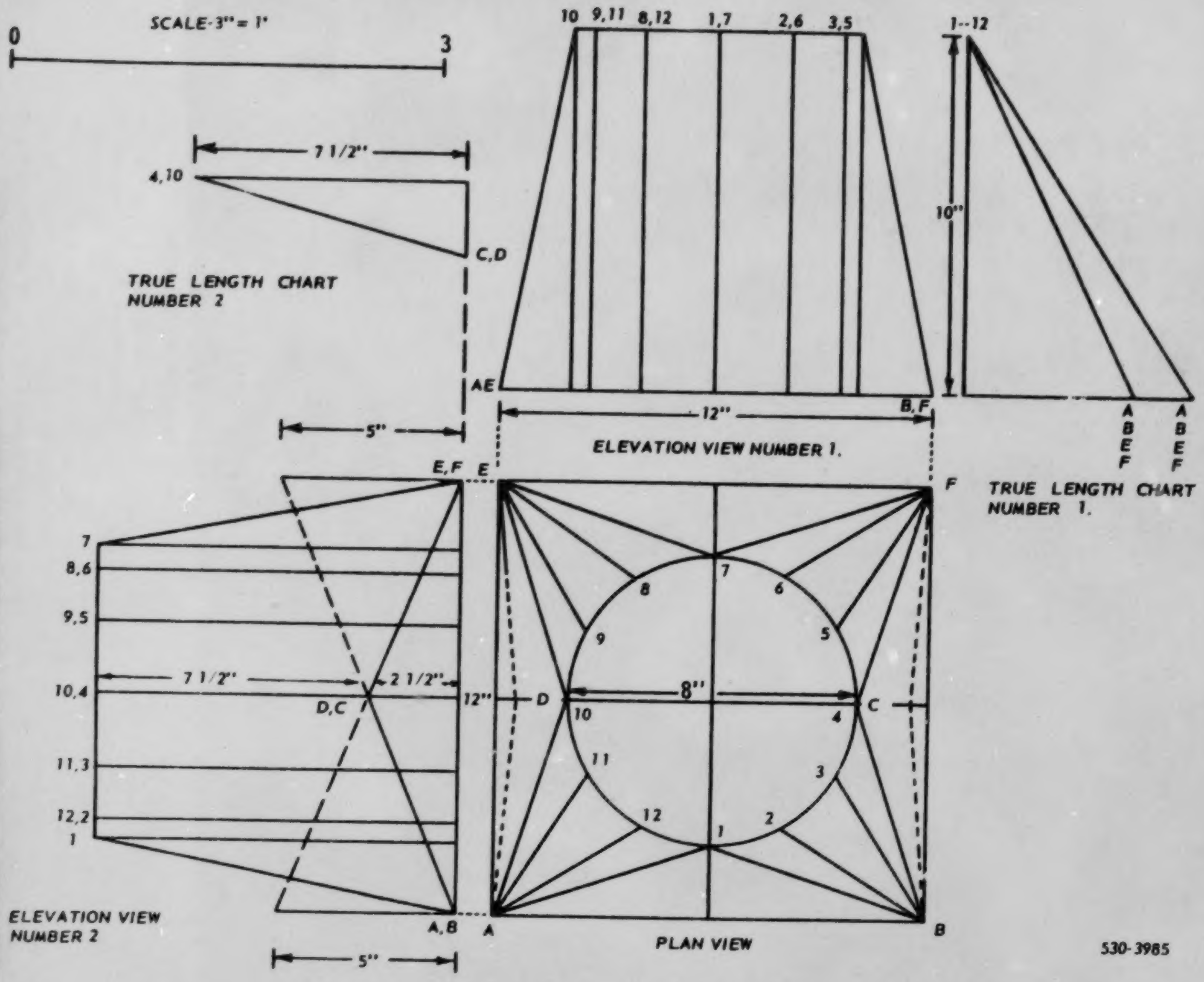

SCALE-3" = 1'
0
3
7 1/2"
4,10
C,D
TRUE LENGTH CHART NUMBER 2
10
9,11
8,12
1,7
2,6
3,5
1--12
10"
AE
B,F
12"
ELEVATION VIEW NUMBER 1.
A B E F
A B E F
TRUE LENGTH CHART NUMBER 1.
5"
E,F
E
F
7
8,6
9,5
10,4
11,3
12,2
1
7 1/2"
2 1/2"
D,C
12"
D
8"
C
1
2
3
4
5
6
7
8
9
10
11
12
ELEVATION VIEW NUMBER 2
A,B
A
B
PLAN VIEW
5"
530-3985

Figure 93. Developing a roof ventilator pattern.

damage is severe, a duplicate ventilator should be installed.

13-4. In some cases, you will fabricate a new or replacement ventilator. As an example, let's make the draft ventilator shown in view B of figure 92. Notice that it consists of a square base that gradually changes to a round pipe, which is covered with a draftproof vent cap, such as that shown in view D of figure 86 and in foldout 2. In this example, the transition is 10 inches high and has a 12" x 12" base that fits over the ridge of a roof with 5 to 12 pitch. The transition is joined to a 1½-inch collar, which joins a straight pipe that is 6 inches long and 8 inches in diameter. The vent cap has a 2-inch airspace between the collar and top and a 2-inch airspace between the collar and ring.

13-5. **Making Patterns for Ventilators.** To develop patterns for ventilators that are regular transitions, you should use the triangulation method of layout and make plan views, elevation views, and true length charts like those shown in figure 93. Elevation view number 1 and its true length chart are made like other regular transition patterns we have discussed in this course. However, elevation view number 2 is somewhat different because of the pitch of the roof. To show the roof pitch on elevation view number 2, draw perpendicular lines 5 inches long from points A,B, and E,F on the base line; then draw diagonal lines from the top of each perpendicular line to points A,B and E,F on the base line. This establishes lines AD, ED, BC, and FC, which represent the 5 to 12 pitch of the roof. To determine if this pitch is drawn correctly, measure from the center of base line AE to point CD. This measurement should be 2½ inches for a 5 to 12 pitch. Another way to check the pitch is to place a protractor on the base line and measure the angles made by the diagonal lines. The angles from points A,B, and E,F should be 22°.

13-6. The true length chart for elevation view number 1 is 10 inches high and has two true length lines to represent slant lines A–1, A–12, A–11, A–10, B–1, B–2, B–3, B–4, E–7, E–8, E–9, E–10, F–4, F–5, F–6, and F–7. These true length lines are used to establish the dimensions of the half pattern shown in figure 94. The true length chart for elevation view number 2 is 7½ inches high. One true length line represents the length of slant lines C–4 and D–10, which are also transferred to the half pattern.

13-7. To develop the half pattern shown in figure 94, you must first draw base line AB 12 inches long, then transfer the other lines from the true length charts in figure 93. After the pattern is developed, include allowances for the grooved seams on the sides and the V-groove at the top, the additions for the flashing, the notches, and the bending instructions. This completes the half pattern for the transition.

13-8. **Cutting and Forming Ventilator Patterns.** After the half pattern is completed and transferred to metal, the two patterns are cut out with straight snips and aviation snips. The Pittsburg lock forming machine is used to form the grooved seams. Be sure to run each pattern through the forming machine so that the pockets of the groove are turned up one half pattern and down on the other. The elements lines A–10 through A–7 are bent up 22½° on the cornice brake. To bend lines B–1 through B–4, insert the pattern under the head of the cornice brake to line B–1 and work the patterns from B–1 to B–4. The 90° and 60° bends are made on the box and pan brake by inserting the edges under the fingers until the bend lines are aligned with the outside edge of the bending leaf. The metal is clamped and partially bent down by hand; then the bending is completed with a mallet.

13-9. **Assembly of a Ventilator.** The two pieces of the transition are joined with the grooved seams, which are then tightened with a mallet and hollow mandrel stake. Flat corner clips are used to fill the gaps at each corner of the flashing and are fastened to the flashing with riveted (or spot-welded) flat lap seams. After riveting (or welding), the lap seams are soldered. The grooved seams that join the transition pieces are also soldered to about 2 inches above the base of the transition.

13-10. A 1½-inch collar is made to fit on the top of the transition. This collar has a V-groove on one edge to fit into the V-groove of the transition. The other edge, which will be the top edge, is crimped to make a slip joint.

13-11. A straight joint 6 inches long and 8 inches in diameter is made, joined to the collar at the slip joint, and secured with sheet metal screws. This straight joint is crimped and beaded at the top end to accept the vent cap. This vent cap is similar to the one shown in foldout 2 except that it is larger.

13-12. **Installation of Ventilators.** Installation of ventilators may be done several ways. To install the turbine ventilator, shown in view A of figure 92, set it on the stack in the same manner that you would install a vent cap and then secure the collar to the stack, making sure the turbine is plumb.

13-13. To install the draft ventilator, shown in view B of figure 92, cut a hole (the size of the base opening) in the roof and roofing felt, nail the base (flashing) to the roof decking, and apply asphalt roofing cement or mop the flashing with hot roofing tar (asphalt) so that the base is

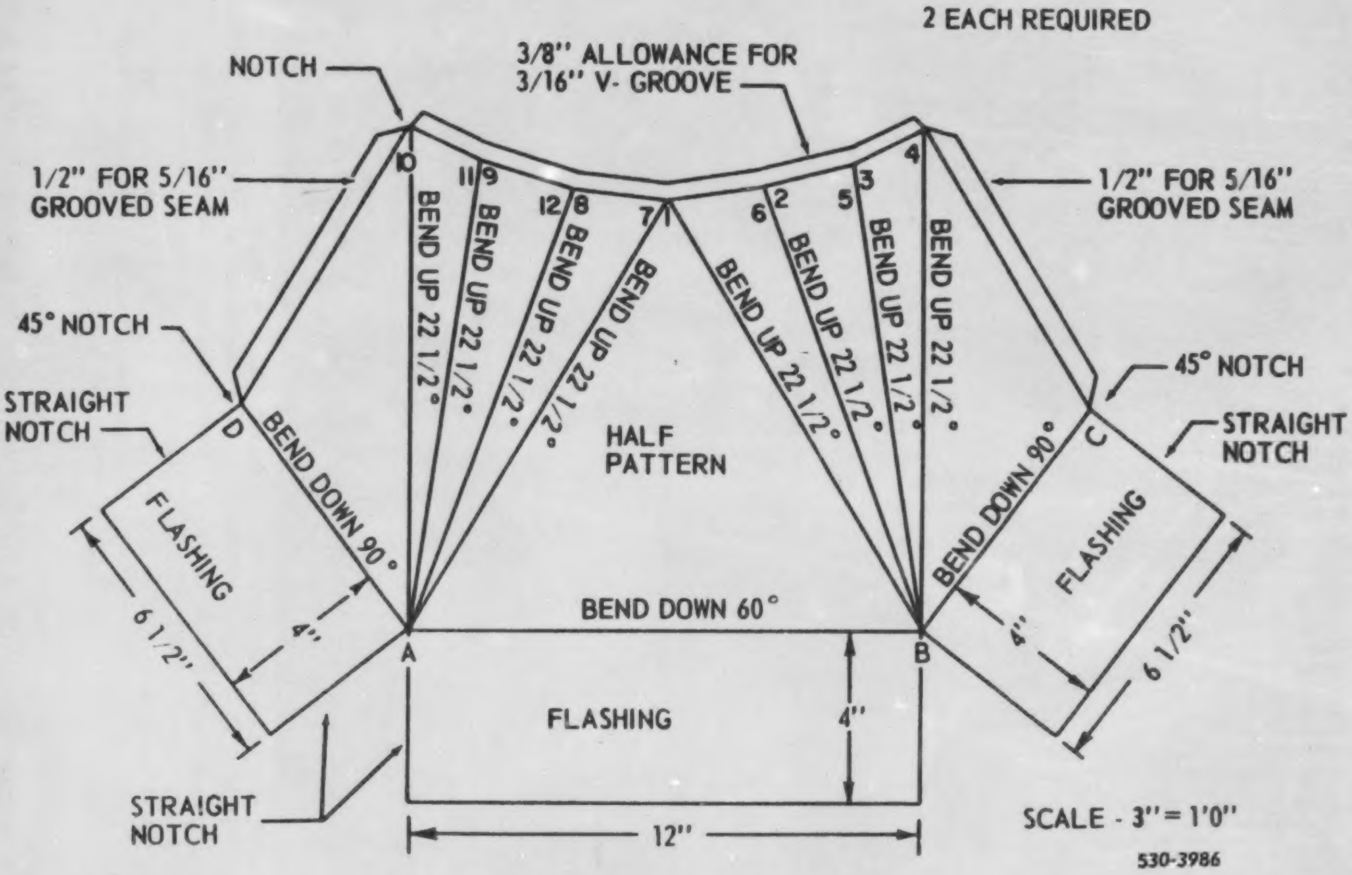

2 EACH REQUIRED
NOTCH
3/8" ALLOWANCE FOR
3/16" V- GROOVE
1/2" FOR 5/16"
GROOVED SEAM
1/2" FOR 5/16"
GROOVED SEAM
10
11
9
12
8
7
1
6
2
5
3
4
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
45° NOTCH
45° NOTCH
STRAIGHT
NOTCH
STRAIGHT
NOTCH
D
C
BEND DOWN 90°
BEND DOWN 90°
HALF
PATTERN
FLASHING
FLASHING
6 1/2"
6 1/2"
4"
4"
BEND DOWN 60°
A
B
FLASHING
4"
STRAIGHT
NOTCH
12"
SCALE - 3" = 1'0"
530-3986

Figure 94. Pattern for a roof ventilator transition.

watertight. As you can see, installation of a draft ventilator is similar to installation of a roof jack.

13-14. The power-operated ventilator, shown in view C of figure 92, is installed so that the base will rest over a box frame and flashing made on the roof. The base of the ventilator has a flange turned down to fit over the box frame. In figure 47, you can see how the flange of a similar ventilator fits over the box frame. The flange should have holes for fastening the ventilator base to the box frame. Several screws should be used to secure the ventilator to the box frame.

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Fabrication, Installation, and Repair of Fixed Utility Equipment

IN THIS CHAPTER we will discuss the fabrication, installation, and repair of indoor and outdoor fixed utility equipment. Indoor fixed utility equipment includes such items as exhaust hoods, serving line equipment, shower stalls, fireproof doors, and fireproof partitions. Outdoor fixed utility equipment includes such items as metal awnings and canopies.

2. Fabrication, installation, and repair of fixed utility equipment will involve information you have already learned in this course, such as pattern layout and cutting, notching, forming, assembly, and installation procedures. You will also learn how to apply this information to stainless steel, which is used for many of the items of indoor fixed utility equipment.

3. The fixed utility equipment items discussed in this chapter are typical of those you will encounter in your job, and the procedures to follow will be similar, although the items may differ in size and shape. What you learn about these items will help you fabricate and install similar jobs more quickly and efficiently.

14. Hoods

14-1. Hoods are used to capture fumes and gases from cooking ranges, coffee urns, dishwashing machines, and paint spray booths. The hood collects the air, which is carried away through a duct by suction created by an exhaust fan. Figure 95 shows a typical hood installed over a cooking range. The height of the lower parts of the hood should be above the heads of personnel who will be working under the hood. For good coverage of air pickup, the hood should extend 6 inches beyond the sides of the range and 12 inches beyond the front. Hoods are usually made of 20-gage stainless steel and have grease filters that can be removed for cleaning. The inside bottom edge of the hood has a flanged edge (lip) that acts as a grease collector or trap. One corner of this grease trap has a drain plug for draining any grease that collects. Figure 96 shows the location and shape of the grease trap. You will encounter hoods of various sizes and shapes; however, the fabrication and installation will be similar to that for the one shown in figure 96

14-2. Hoods are usually supported by hangers that are adjustable so that a corner can be lowered to allow the grease to drain from the plug. Hood hangers, like duct hangers, are fastened to the ceiling joists and are made of flat bar, rod, or chain. A turnbuckle or device with similar purpose is used for adjusting the height of the front corners of the hood.

14-3. Fabrication of hoods from stainless steel is similar to fabrication of other sheet metal components except that stainless steel is a harder metal and the polished surface will scratch easily. Some manufacturers apply an adhesive paper to the surface of stainless steel sheets for scratch protection. During layout and fabrication, this paper is left on the metal. Pencil lines marked on the paper can be seen better than marks on the surface of the steel. Leave this paper on the metal until the component is assembled and installed.

14-4. To fabricate a hood, you need to know the dimensions and shape. Figure 96 shows pictorial views and details of a hood that measures 8 feet long and 30 inches wide. It has a filter that fits inside the collar and a drain plug in one corner of the grease trap. The collar at the top of the hood where the exhaust duct connects is 2" x 12" x 20". The corners of the grease trap and the standing seams are secured with Monel rivets.

14-5. **Pattern Layout for a Hood.** In figure 96 you can see that the hood is shaped like a transition. You should remember from Volume 1 that the triangulation method of layout is used to develop patterns for transitions. This hood can be made in four pieces, as shown in figures

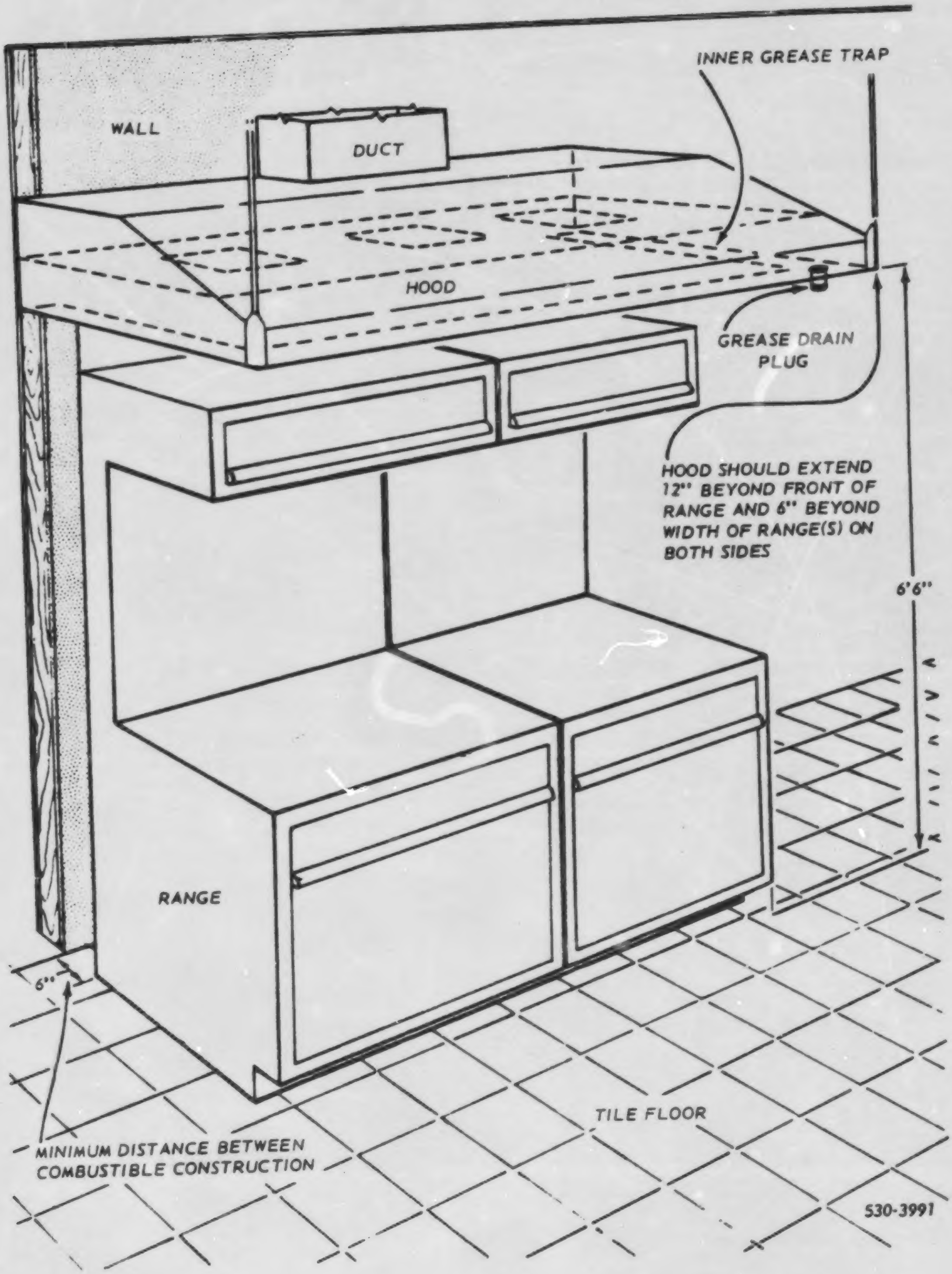
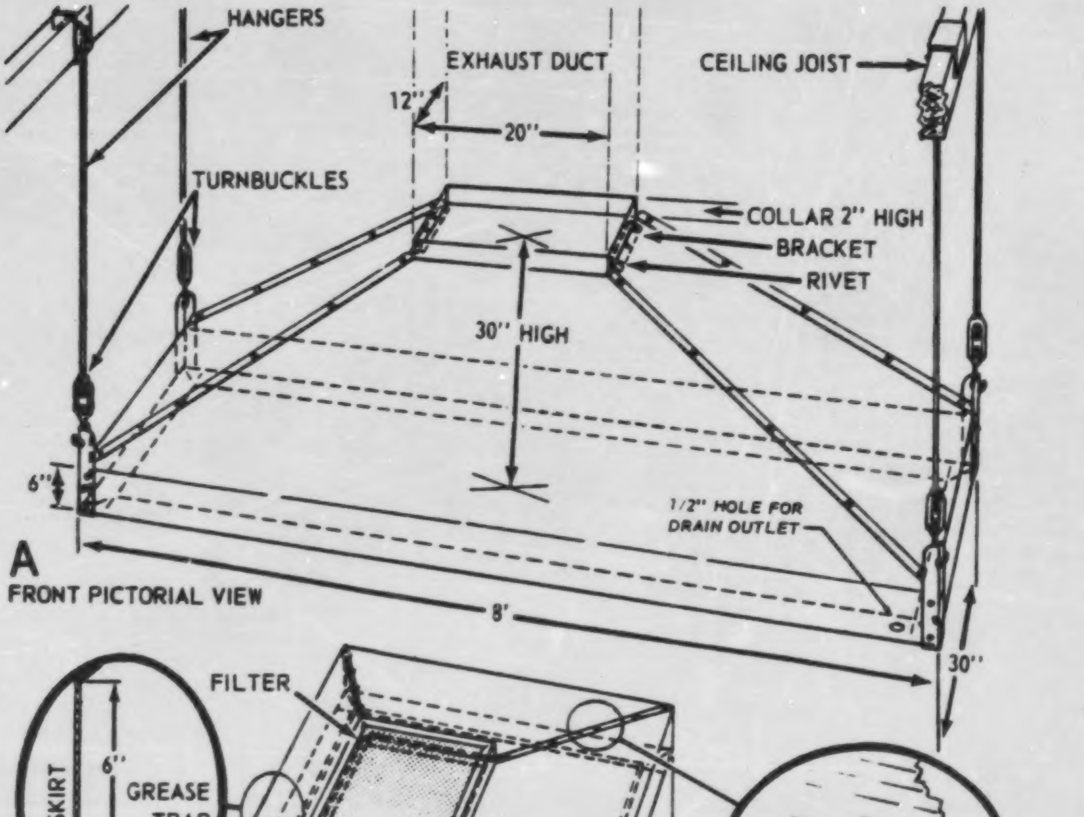

INNER GREASE TRAP
WALL
DUCT
HOOD
GREASE DRAIN PLUG
HOOD SHOULD EXTEND 12" BEYOND FRONT OF RANGE AND 6" BEYOND WIDTH OF RANGE(S) ON BOTH SIDES
6'6"
RANGE
6"
TILE FLOOR
MINIMUM DISTANCE BETWEEN COMBUSTIBLE CONSTRUCTION
530-3991

Figure 95. Hood installation over a range.


HANGERS
EXHAUST DUCT
CEILING JOIST
12''
20''
TURNBUCKLES
COLLAR 2'' HIGH
BRACKET
RIVET
30'' HIGH
6''
1/2'' HOLE FOR DRAIN OUTLET
A
FRONT PICTORIAL VIEW
8'
30''
FILTER
SKIRT
6''
GREASE TRAP
1/2''
2''
RIVET
STANDING SEAM
8'
6''
B
END PICTORIAL VIEW
30''
RIVETS
530-3992

NOTE:
MAKE HOOD FROM 20-GAGE STAINLESS STEEL

Figure 96. Pictorial views of a hood.

97 and 98. Notice that the front, back, and two sides will each be one piece.

14-6. A plan view of the transition is required so that certain points can be transferred to the true length chart. The height of the true length chart in figure 97 is 24 inches, which is the vertical distance from the 6-inch skirt to the collar. (The 6-inch skirt is an addition to the pattern and is not shown in figure 97.) To draw the plan view, a rectangle 8 feet long and 30 inches wide is needed with the 12″ x 20″ outlet drawn at the center. A good way to find the center is to locate the middle of each side of the 8′ x 30″ rectangle and draw lines F–E and 1–6. The 12″ x 20″ rectangle outlet can be drawn in because these lines will also be the center of the large rectangle. After the two rectangles are drawn and numbered as shown in figure 97, draw connecting lines between the letters and numbers.

14-7. The next step in developing the patterns is to find the true length of the lines between the rectangles of the plan view. Begin the true length chart with a 90° angle which has the vertical leg 24 inches high to represent the vertical height from the skirt to the collar. Use dividers (or trammel points) and measure the length of line 1–2 and 6–5 on the plan view. These lines should be the same, and this distance is transferred to the base line of the true length and identified as point 1, 6. Draw a line from point 1, 6 on the base line to the top of the 24-inch vertical line and write 2, 5 to identify the vertex point. The length of slant line 1, 6 to 2, 5 is the height of the front and back pieces for the hood. Next, transfer the distance from 3 to E (or 4 to F) to the true length chart, draw the slant line, and label the bottom end 3, 4 and the top end E,F. This slant line is the slant height of the two side pieces of the hood. Next, transfer the distance from points 2 to A to the true length chart, draw the slant line, and label the ends. This slant line is the same for 2–B, 5–C, and 5–D and will be used later to develop the pattern for the front and back. Line 4–A when transferred to the true length chart will be the slant height. Transfer line 4–T to the true length chart, draw the slant line, and lable to represent points 3 and 4 and points A, B, C, and D. The last line to be transferred is 7–A, which is the slant height of the edge of the pattern along the standing seams. All four corner lines should be the same length.

14-8. *Patterns for the front and back.* The true length chart is now complete enough to develop the patterns shown in figure 98. Since the patterns are identical except for bending instructions, only one pattern need be developed. Begin by drawing a straight line 8 feet long; letter one end A, D and the other end B, C. Notice how this line corresponds to the same lettered lines in the plan view of figure 97. Next, transfer the length of line A–1 from the plan view to the pattern, and label the midpoint 1,6. Next, set the dividers (or trammel points) to the length of line A–2 in the plan view and transfer it to the pattern. With this setting, draw a short arc above point 1,6. Keep the same setting, move one tip of the dividers to point B, and swing an arc that crosses the arc made in the preceding step. The point where these two arcs meet is point 2,5. Next, transfer line 1–2 from the true length chart to the pattern; the top end of this line should be at point 2,5 where the two arcs crossed. Connect points 1,6 and 2,5 with a dashed line which is the height (slant height) of the front and back pieces of the pattern. Draw a 20-inch line through point 2,5 that is parallel to line A,D—B,C. Transfer the length of line 2–8 from the plan view to the pattern, and swing an arc on both sides of point 2,5. The arcs establish points 7,10 and 8,9, which are the 20-inch sides of the collar. Next, transfer the length of line A–7 from the plan view to make lines A–7 and B–8 on the pattern. This completes the pattern, except for the additions and seam allowances.

14-9. The additions and seam allowances for the front and back pattern shown in figure 98 are made from information contained in the pictorial views of figure 96. Make the additions below the 8-foot line on the pattern as follows: 6 inches for the skirt, 2 inches for the lip of the grease trap, ½ inch for the flange of the grease trap, and 7/16 inch for the hem. At the top of the pattern, a 2-inch addition is made for the collar. Make a 1-inch allowance on each side for the 90° flange portion of the standing seam. The next step is to write the bend instructions for the lines on the pattern. Notice that figure 98 has bending instructions for the back pattern with a statement that the instructions for the front pattern are opposite.

14-10. Notches for the front and back pattern are somewhat different from those for other patterns discussed previously in this text. Notice in figure 98 how the 2-inch addition for the grease trap lip is slant notched at each end and that the same addition on the side pattern is not slant notched. The reason for this is that when the corners are joined, the 45° cut will be on the outside of the lap joint, and the mitered cut makes a more attractive corner. Figure 96 shows how this corner will look and where the rivets are located. Now back to figure 98, notice that the ½-inch flange addition and the 7/16-inch hem

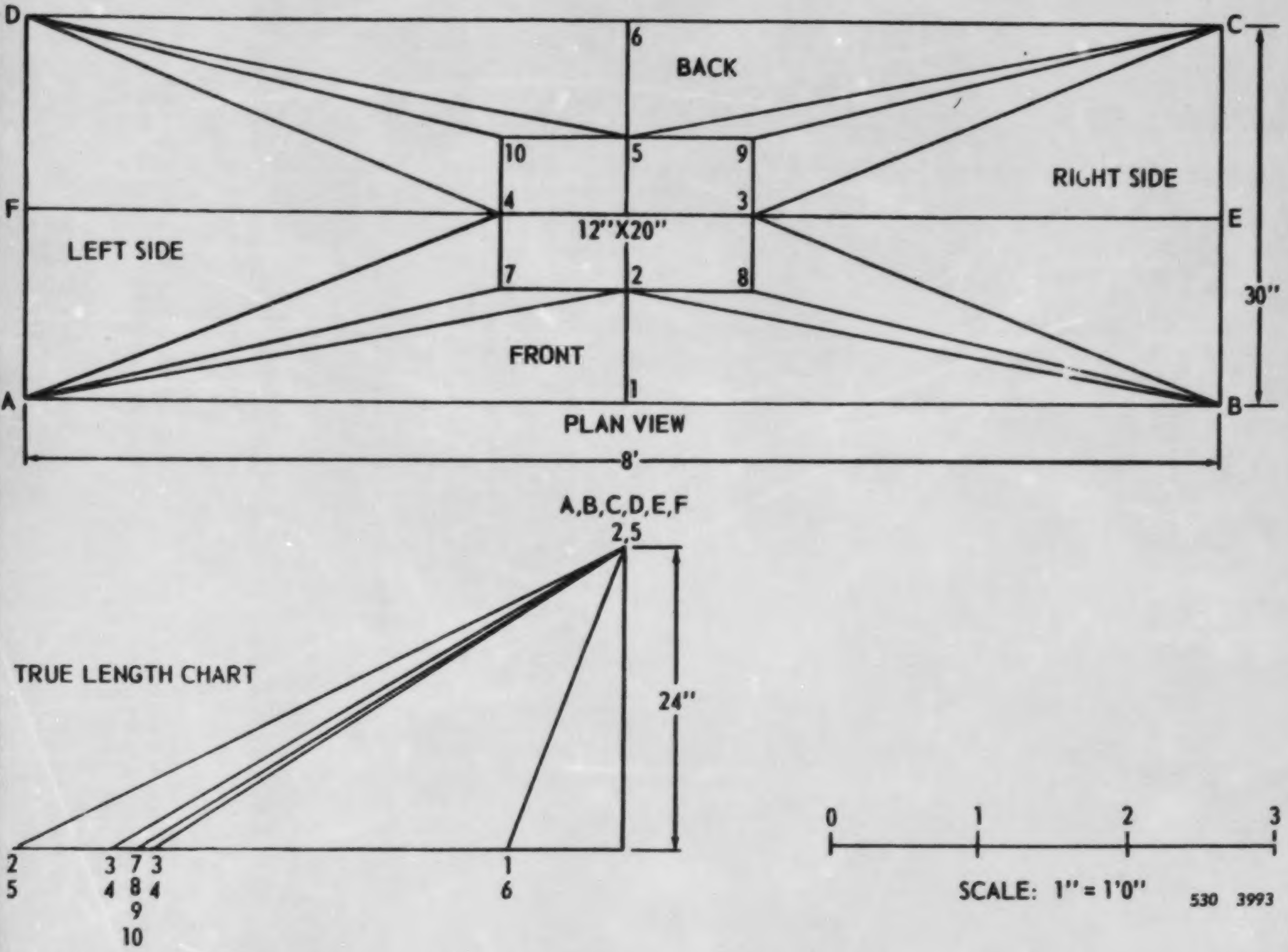

D
C
6
BACK
10
5
9
RIGHT SIDE
F
4
3
E
12"X20"
LEFT SIDE
7
2
8
30"
FRONT
1
A
B
PLAN VIEW
8'
A,B,C,D,E,F
2,5
TRUE LENGTH CHART
24"
2
5
3
4
7
8
9
10
3
4
1
6
0
1
2
3
SCALE: 1" = 1'0"
530 3993

Figure 97. Plan view for developing patterns for a hood.

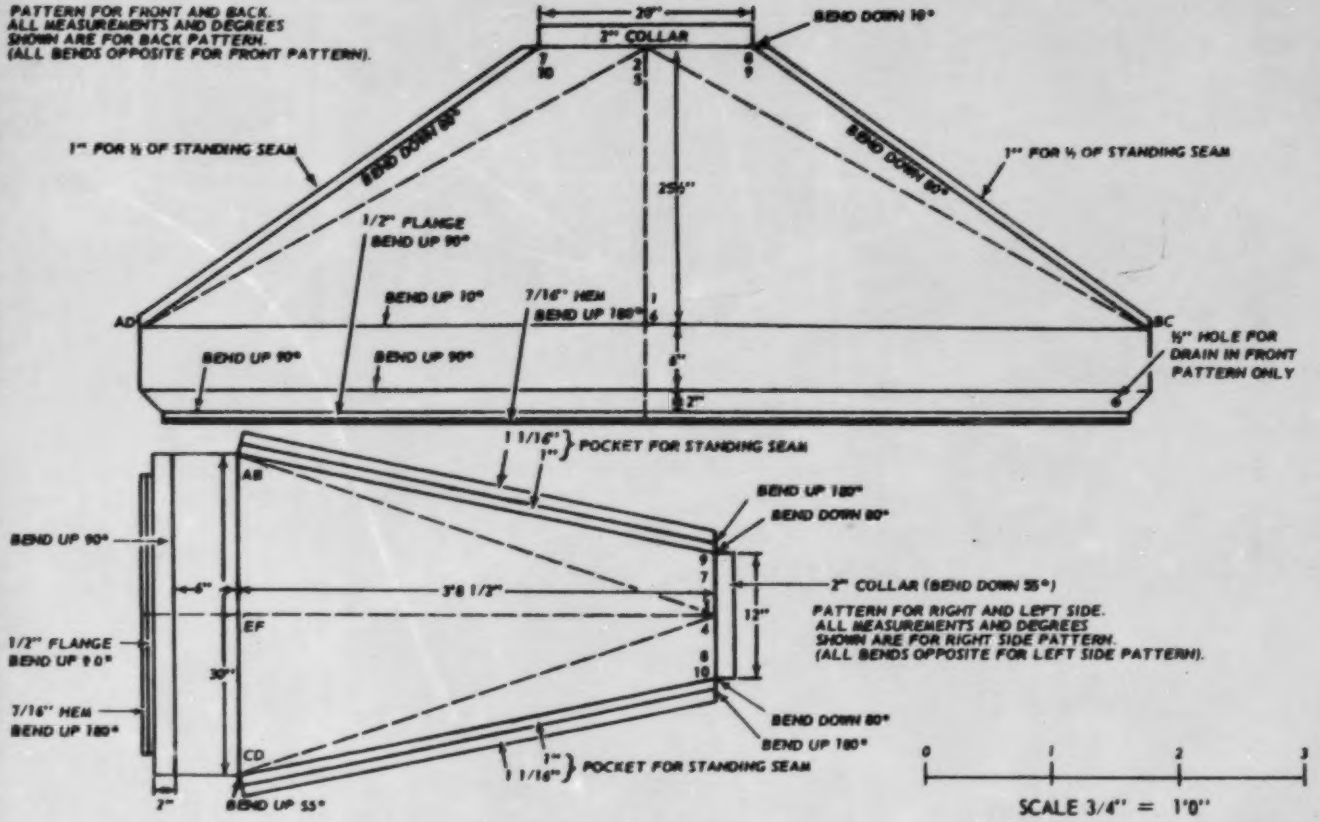

PATTERN FOR FRONT AND BACK.
ALL MEASUREMENTS AND DEGREES
SHOWN ARE FOR BACK PATTERN.
(ALL BENDS OPPOSITE FOR FRONT PATTERN).
20"
2" COLLAR
BEND DOWN 10°
7 10
2 5
8 9
1" FOR ½ OF STANDING SEAM
BEND DOWN 80°
BEND DOWN 80°
1" FOR ½ OF STANDING SEAM
25½"
1/2" FLANGE
BEND UP 90°
BEND UP 10°
7/16" HEM
BEND UP 180°
1 6
AD
BC
½" HOLE FOR
DRAIN IN FRONT
PATTERN ONLY
BEND UP 90°
BEND UP 90°
6"
2"
1 1/16"
1"
POCKET FOR STANDING SEAM
AB
BEND UP 180°
BEND DOWN 80°
BEND UP 90°
9
7
6"
3'8 1/2"
2" COLLAR (BEND DOWN 55°)
12"
PATTERN FOR RIGHT AND LEFT SIDE.
ALL MEASUREMENTS AND DEGREES
SHOWN ARE FOR RIGHT SIDE PATTERN.
(ALL BENDS OPPOSITE FOR LEFT SIDE PATTERN).
EF
4
8
10
1/2" FLANGE
BEND UP 90°
30"
7/16" HEM
BEND UP 180°
BEND DOWN 80°
BEND UP 180°
CD
1"
1 1/16"
POCKET FOR STANDING SEAM
2"
BEND UP 55°
0
1
2
3
SCALE 3/4" = 1'0"
530-3994

Figure 98. Patterns for a hood.

allowance are notched at 90° so that they will make butt joints when the corners are joined. The 2-inch allowance for the collar has 90° notches. The standing seam allowance on the front and back pattern is slant notched at each end.

14-11. *Patterns for the sides.* The pattern for the two sides of the hood is developed from the true length chart (fig. 97), using procedures similar to those used to make the front and back patterns. The completed pattern for the sides is shown in figure 98 and includes the dimensions, additions, seam allowances, bend instructions, and notching instructions. The pattern illustrated is for the right side of the hood. The pattern for the left side is identical except for the bending instructions, which will be opposite to those for the right side.

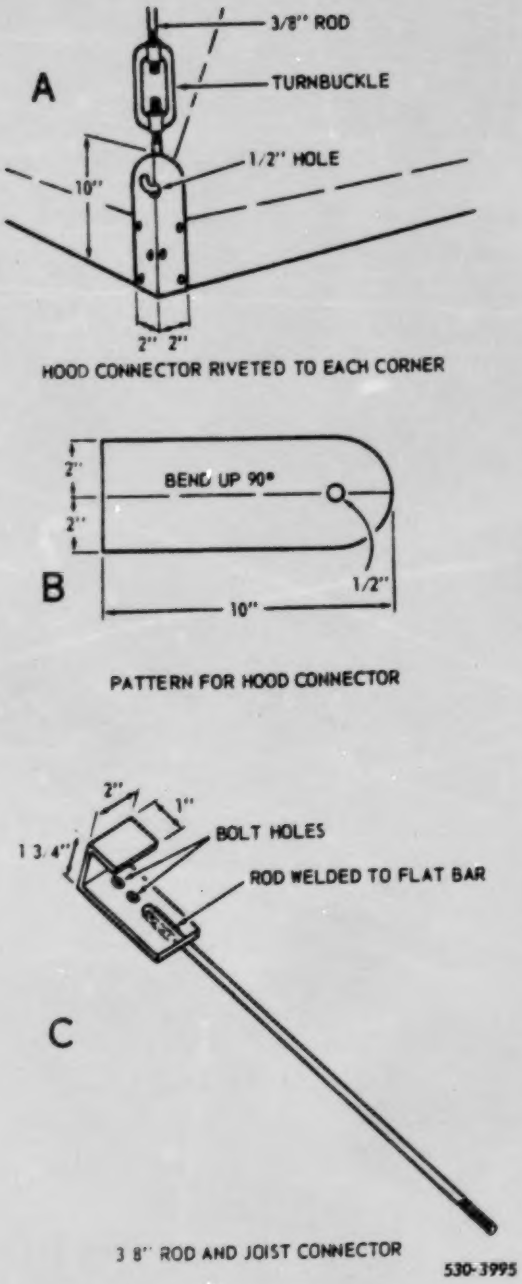
14-12. **Cutting and Notching Patterns for a Hood.** Cutting and notching the patterns for the hood shown in figure 98 will require squaring shears and straight snips. The outside edges of the side patterns are cut with the squaring shears. The front and back patterns are cut with the squaring shears, except for the edge of the standing seam. If this edge seam is cut with the squaring shears, the corners of the 2-inch collar will be clipped; therefore, straight snips are used. The notches on both patterns are cut with straight snips.

14-13. **Forming the Patterns for a Hood.** The bending instructions are shown in figure 98, notice that the instructions for the bends for the front side and left side patterns are opposite to the instructions written on the illustration. Starting with the *back pattern*, use the cornice brake to bend the standing seams 80°. After they are bent, about 2 inches of each seam near ends C and D must be straightened back out with a mallet and wood block. This is necessary so that the cornice brake will not damage the metal when it is clamped to make the 10° bend along line C-D. After this is done, the following bends can be made: the 180° bend for the hem addition, the 90° bend for the ½-inch flange addition, and the 90° bend for the 2-inch grease trap addition. The last bend to make are the 10° bends for the 6-inch skirt and 2-inch collar additions. After all of these bends have been made, use a mallet and wood block to reshape the ends of the standing seams which were temporarily straightened out. The *front pattern* is formed using procedures similar to those used to make the back pattern except that the instructions are reversed and that a hole for the drain plug is made with a rotary punch.

14-14. Two forming machines are needed to make the bends on the patterns for the side pieces: the cornice brake and the box and pan brake. The bending instructions are shown on figure 98. To form the pattern for the *right side*, make the 180° and 80° bends with the cornice brake for the pocket of the standing seams. It is not necessary to temporarily straighten the ends of the seam because the box and pan brake will be used to make the remaining bends. Arrange the fingers of the box and pan brake to make bends 30 inches long, and then make the following bends: 180° for the hem addition, 90° for the ½-inch flange addition, 90° for the 2-inch grease trap addition, and 55° for the 6-inch skirt addition. To make the 55° bend, the pattern must be turned over in the box and pan brake (along the outside edge of the lower bending leaf) and bent down with a mallet so that the standing seam will not be damaged. Arrange the fingers of the box and pan brake to make a bend 12 inches long; then make the 55° bend for the 2-inch collar addition. This bend can be made with the machine only; the mallet is not used.

14-15. **Assembly of a Hood.** Now that the pieces are cut, notched, and formed, the hood shown in figure 96 can be assembled. You can begin at any one of the four corners and insert the grease trap of a side piece into the grease trap of the front (or back) piece. The 45° miter cut on the front (and back) piece should be on the outside of the lap seam. It is necessary to hold the side piece at an angle to allow the 1-inch flange to be inserted in the pocket of the standing seam. When the two pieces are joined and the corners of the skirt and collar are square, use a small C-clamp or vise grip pliers at each end of the standing seam to temporarily hold it together while the other pieces are assembled. Be sure to use cardboard or small blocks of wood to keep the clamps from scratching the metal. Continue this procedure until all four pieces of the hood are assembled. Inspect each seam and butt joint for proper fit, and when everything is satisfactory, install Monel rivets in each of the standing seams. For good appearance and holding strength, the first three rivets can be located as follows: one at the midpoint and one 2 inches from each end of the standing seam. The remaining rivets should be spaced on 8- to 10-inch centers. After riveting, remove the clamps from the standing seams.

14-16. The next part of the assembly procedure is to install Monel rivets at the corners of the grease trap. It is important that the corners are square before the rivets are installed. Carefully lay the hood on its front or back and use a carpenter's square. Install clamps at each corner to hold the corners until the rivets are installed.



HOOD CONNECTOR RIVETED TO EACH CORNER

PATTERN FOR HOOD CONNECTOR

3/8" ROD AND JOIST CONNECTOR

Figure 99. Hanger parts.

You can double check the squareness of the skirt corners by measuring the corners diagonally. The diagonals should be the same if all corners are square. After you are certain that the hood is square, install Monel rivets in each of the four corners of the grease trap, as shown in figure 96. Solder the inside of the corner lap joint with 50/50 solder.

14-17. For the drain outlet, get a ½-inch stainless steel pipe coupling and have the welding shop solder it over the outlet opening with silver solder. Silver solder will be much stronger than regular solder for this purpose.

14-18. The two brackets to hold the filter are each made of stainless steel 1" x 11" and bent 35° along the 11-inch centerline. These brackets are fastened to the sides of the hood with three Monel rivets near the collar, as shown in figure 96. The filter rests on the ½-inch edge of metal that extends into the opening and is removed by raising one end until the other end clears the bracket.

14-19. The corners of hoods are supported with hanger parts, such as those shown in figure 99. Notice that the parts include a corner connector, turnbuckle, rod, and joist connector. The corner connector is made of 16-gage stainless steel, using the pattern shown in view B, and is made long enough to extend 4 inches above the skirt of the hood. Cut the straight sides with the squaring shears, cut the rounded end with throatless shears, punch the ½-inch hole with a rotary punch, and make the 90° bend with a cornice brake. Each corner connector is attached to the hood with Monel rivets, as shown in view A of figure 99.

14-20. The remaining parts of the hood hanger, shown in view C of figure 99, are made by the welding shop. A ⅜-inch rod is threaded at one end and welded at the other end to a piece of 2-inch flat bar which is formed to fit over the ceiling joist. A short piece of the ⅜-inch rod is threaded at one end, and the other end is heated and bent to make a hook. The threads must be made to fit the turnbuckle. The length of the rods is determined by the distance from the ceiling joists to the desired height of the hood.

14-21. **Installation of a Hood.** Before hanging a hood, such as that shown in figure 96, determine the location from the drawings of blueprints, then hook the joist connectors (fig. 99) over the ceiling joists. With the hangers located so that the round rod hooks can be inserted into the corner connectors when the hood is raised into position, have three or more men raise the hood and insert the hooks into the corner connectors. Level the hood by adjusting the turnbuckles; a slight drop toward the drain corner should be made so that the grease will drain when the plug is removed. Use wood screws and fasten each joist connector to the ceiling joists. The final steps of installation are to connect the exhaust duct, remove the adhesive paper from the stainless steel, and install the filter.

15. Serving Line Equipment

15-1. The serving line counter, shown in figure 100, is a typical piece of serving line equipment used in dining halls. Special equipment is needed to work heavy-gage stainless steel and to polish the surfaces; therefore, your job will normally be to repair and replace components made of sheet metal. Most serving lines are installed when dining halls are built or are installed on contract jobs.

15-2. The top of the serving line counter is made of 14-gage stainless (corrosion-resistant) steel and is fastened to an angle iron or channel iron frame with bolts that have been welded to the underside of the top.

15-3. The front and side panels are made of lighter gage metal than the top, usually 18, 20, or 22 gage, according to the specifications. These panels are usually 4 feet wide (the width of a sheet) and are joined with butt joints covered with cap strips. The cap strips are made from 14-gage stainless steel in lengths necessary to

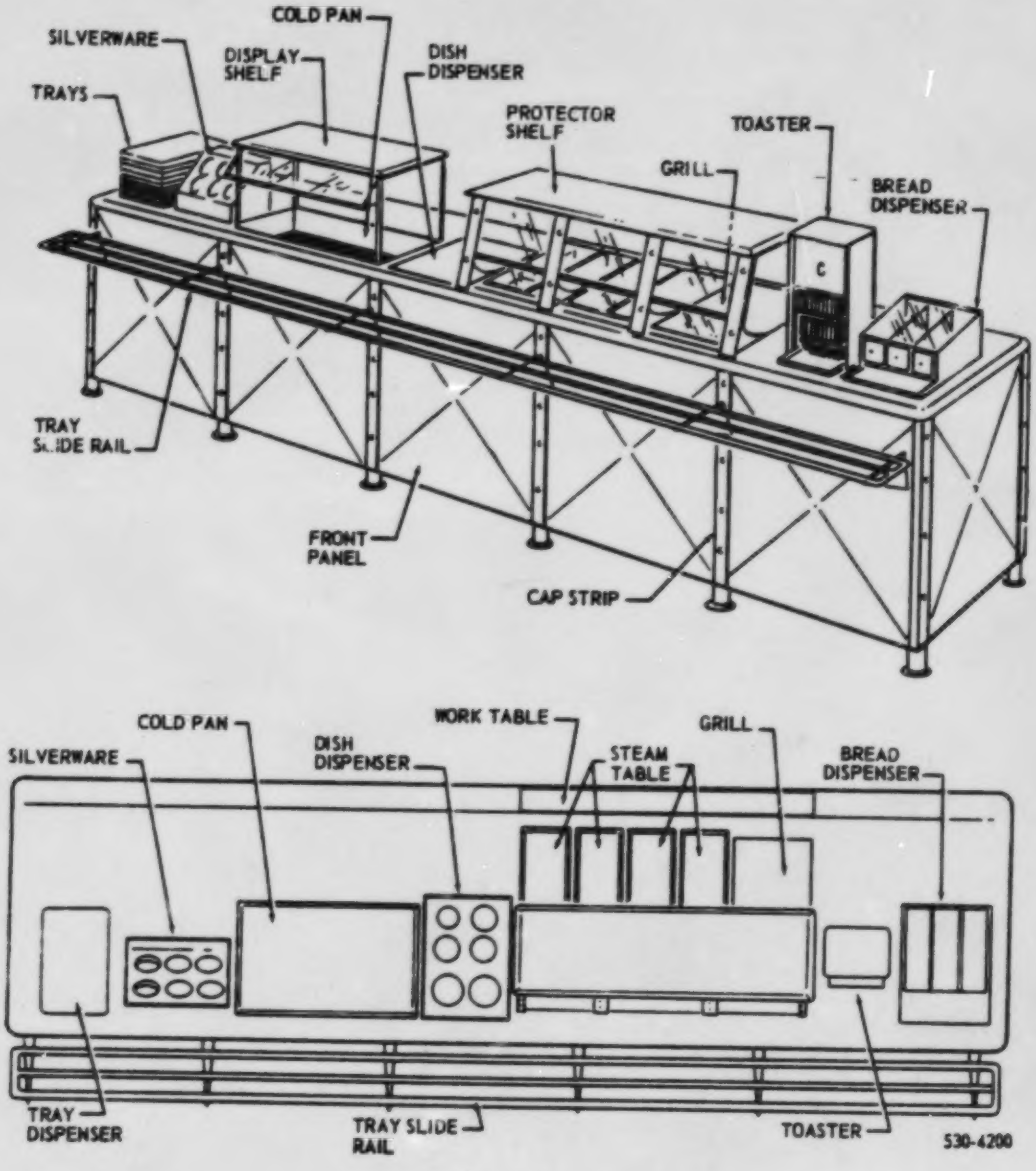

COLD PAN
SILVERWARE
DISPLAY SHELF
DISH DISPENSER
TRAYS
PROTECTOR SHELF
TOASTER
GRILL
BREAD DISPENSER
C
TRAY SLIDE RAIL
FRONT PANEL
CAP STRIP
COLD PAN
WORK TABLE
GRILL
SILVERWARE
DISH DISPENSER
STEAM TABLE
BREAD DISPENSER
TRAY DISPENSER
TRAY SLIDE RAIL
TOASTER
530-4200

Figure 100. Serving line counter.

334

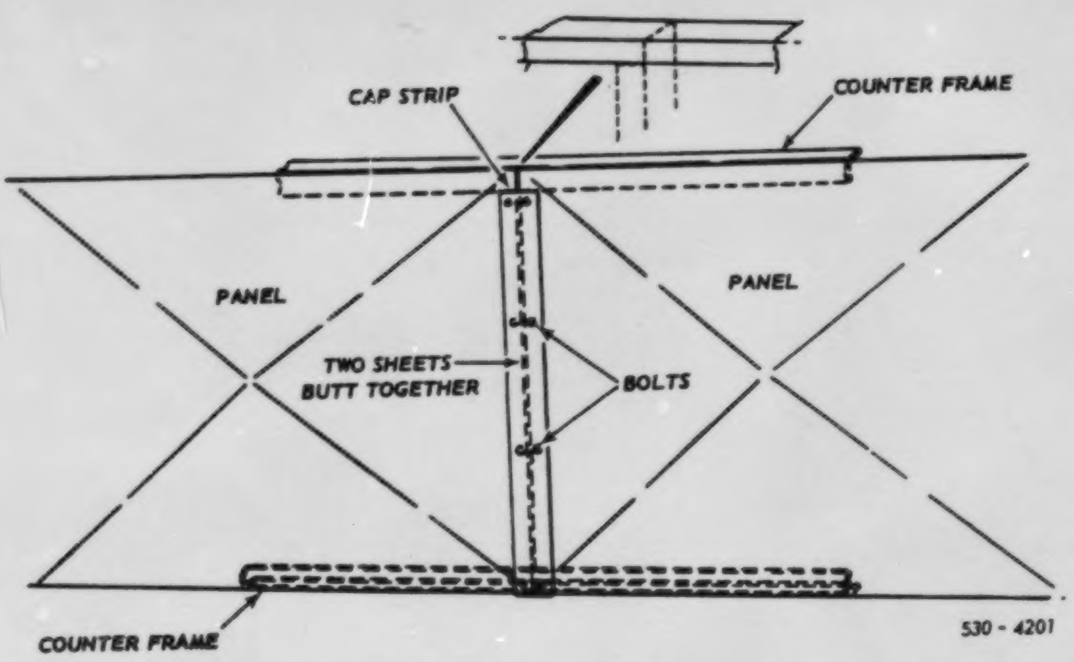


Figure 101. Stainless steel cap strip.

cover the butt joints. The width of the cap strips is usually 1½ inches to 2 inches wide, since the frame of the counter should have 1½" x 1½" angle iron vertical braces where the panels are joined. The cap strips are fastened to the panels and angle iron with corrosion-resistant steel bolts. In figure 101 you can see how a cap strip is used to cover a butt joint.

15-4. The three slide rails for trays shown in figure 100 are constructed of 1-inch stainless steel tubing. The rails are supported by brackets made from chromium-plated cast brass or stainless steel. The supporting brackets should not be spaced over 4 feet apart; they are fastened to the serving line with corrosion-resistant bolts.

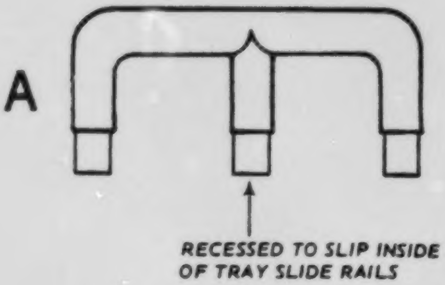
15-5. The display shelf (over the cold pan), shown in figure 100, has three ¼-inch plate glass shelves that are bound on the edges with stainless steel. The frame uprights are made of 1-inch square or round stainless steel tubing. The shelves are usually 18 inches wide and as long as desired. The upright supports are spaced not more than 42 inches apart. Each shelf is supported with ⅝-inch square tubing that is welded to the uprights and braced with a V-shaped corner clip. The corners have clips welded to hold the glass shelves in place.

15-6. The top of the protector shelf over the steamtable portion of the counter is usually made of stainless steel 16 inches high, 8 inches wide at the top, and 12 inches wide at the bottom. The front of the protector shelf is made of ¼-inch glass panels that are edged with stainless steel channel strips. The shelf is supported by braces that are chromium plated. The fronts of the braces are slotted so that the panels of glass will fit into place; cover plate with screws holds the glass panels securely. The protector shelf rests on the braces and is fastened with bolts that have been welded to the bottom of the shelf. The bottoms of the braces are tapped so that they can be mounted with bolts through the counter top.

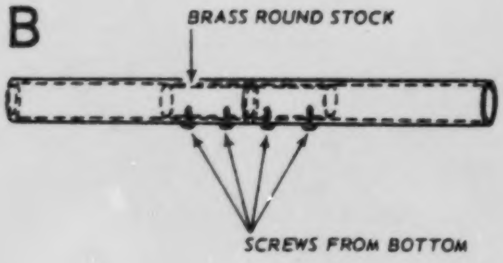
15-7. The legs of the counter are adjustable and are mounted to the counter frame. The legs are usually tubing or pipe. If they are stainless steel, the tubing will be 16 gage and 1⅝ inches in diameter. If the legs are chromium-plated pipe, they will be 1¼ inches in diameter. The legs are bolted or welded to the counter frame according to the type being used and are spaced not over 48 inches apart.

15-8. **Replacing a Stainless Steel Panel.** Replacing stainless steel panels is one of the jobs you may be required to do; therefore, suppose the right end panel of the counter shown in figure 100 needs replacing. The old panel should be removed and measurements taken from it. To remove the panel, remove the corner cap strips and any screws that may be holding the panel to the counter frame. In this example, the panel to be repaired is 30 inches wide and 36 inches long, with a 1½-inch flange on the bottom to fit around the angle iron frame of the counter. Use the squaring shears to cut a piece of 20-gage stainless steel large enough to make the panel. After cutting the metal, use the cornice brake to make the cross brake bends and the flange.

15-9. When cutting and forming the stainless steel, you will notice that the machines require more force to operate than when forming mild steel. This is because of the toughness characteristics of stainless steel. For example, shears designed to cut ¼-inch mild steel will only cut up to ³⁄₁₆ inch of stainless steel without overloading the machine. When using the forming equipment in your shop, remember that the capacity ratings of cutting and forming machines are for mild steel and do not apply to stainless steel. Refer to the technical manuals or manufacturers' handbooks for the capacity ratings for stainless steel. When forming stainless steel, you will notice there is more springback than from mild steel. This is because of the elasticity characteristic of stainless steel. After cutting and forming the panel, you are ready for its installation. Fit the panel into place, and reinstall the cap strips. Reinstall any other fasteners that are used to hold the panel in place.



END PIECE FOR JOINING RAIL



SPLICE

530 - 4202

Figure 102. Repair of a tray slide rail.

15-10. **Repairing a Tray Rail.** Repairing a tray rail of a serving line counter, such as that shown in figure 100, will usually consist of replacing screws that have worked loose where the rail is fastened to the bracket or where splices have been made. The ends of most rails have a chromium-plated end piece like the one shown in view A of figure 102. The hollow rails (tubing) slide over the recessed ends and are secured with screws. The recess allows the rails to fit flush with the end piece to make a nice fit. Because of the length of some serving lines and the lengths in which the rails are purchased, it is sometimes necessary to make splices. This can be done by welding and polishing or by the method shown in view B of figure 102.

15-11. If a tray rail becomes damaged, you can replace a section in several ways. Suppose that the outside rail in figure 100 is bent 6 feet from the right end and requires replacement. Examination reveals that the ends are joined with a piece like the one shown in view A of figure 102 and that the rail is spliced 10 feet from the right end, as shown in view B.

15-12. To make the repair, remove the end piece and all of the fasteners holding the rail to the braces. Remove the screws on the right side of the splice, and pull the 10-foot section loose. In this example, the 10-foot section will be replaced with a new one, but you have only a 5-foot section of new tubing. This means that you must use 5 feet of the old rail. Be sure to make a straight cut. If possible, use a bandsaw or power-operated hacksaw for the cut. Use a piece of brass round stock about 6 inches long, such as that shown in figure 102, for the splice so that it will cover enough area inside the tubing to make a strong splice. Drill and tap the holes in the bottom side of the tubing and round stock, fit the two 5-foot pieces together, and secure with 10–32 roundhead screws. When you return to the job, the 10-foot section can be replaced and the end piece reinstalled. Be sure to fasten the rail to the tray rail brackets.

15-13. **Replacing a Tray Rail Bracket.** Tray rail brackets that are chromium-plated should be replaced with new ones because welding will remove the chromium plating. However, if a bracket is made from stainless steel, you can make a replacement such as that shown in figure 103. Notice in view A how the rails are fastened to

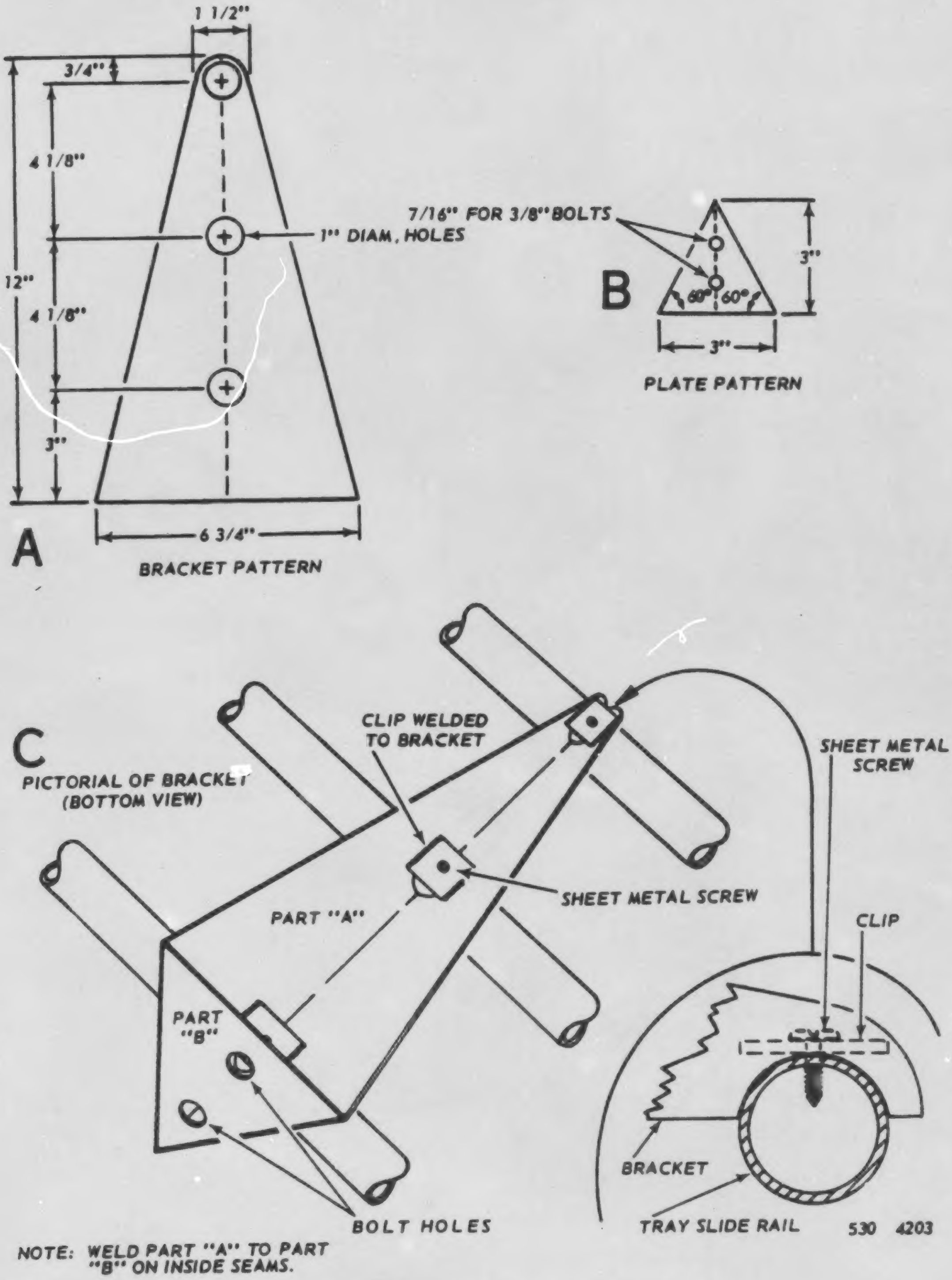

1 1/2"
3/4"
4 1/8"
12"
4 1/8"
3"
1" DIAM. HOLES
6 3/4"
A
BRACKET PATTERN
7/16" FOR 3/8" BOLTS
3"
B
60°
60°
3"
PLATE PATTERN
C
PICTORIAL OF BRACKET
(BOTTOM VIEW)
CLIP WELDED
TO BRACKET
SHEET METAL
SCREW
SHEET METAL SCREW
PART "A"
CLIP
PART
"B"
BRACKET
BOLT HOLES
TRAY SLIDE RAIL
530 4203
NOTE: WELD PART "A" TO PART
"B" ON INSIDE SEAMS.

Figure 103. Support bracket for a tray slide rail.

the bracket clips with self-tapping sheet metal screws from the bottom.

15-14. To fabricate the bracket, make patterns like the ones shown in views A and B of figure 103. Be sure to punch the holes before the bracket is formed. After bending the bracket through the centerline for the holes, weld the plate pattern to the bracket. This weld should be made from the inside. Make the clips and weld them to the underside of the bracket just

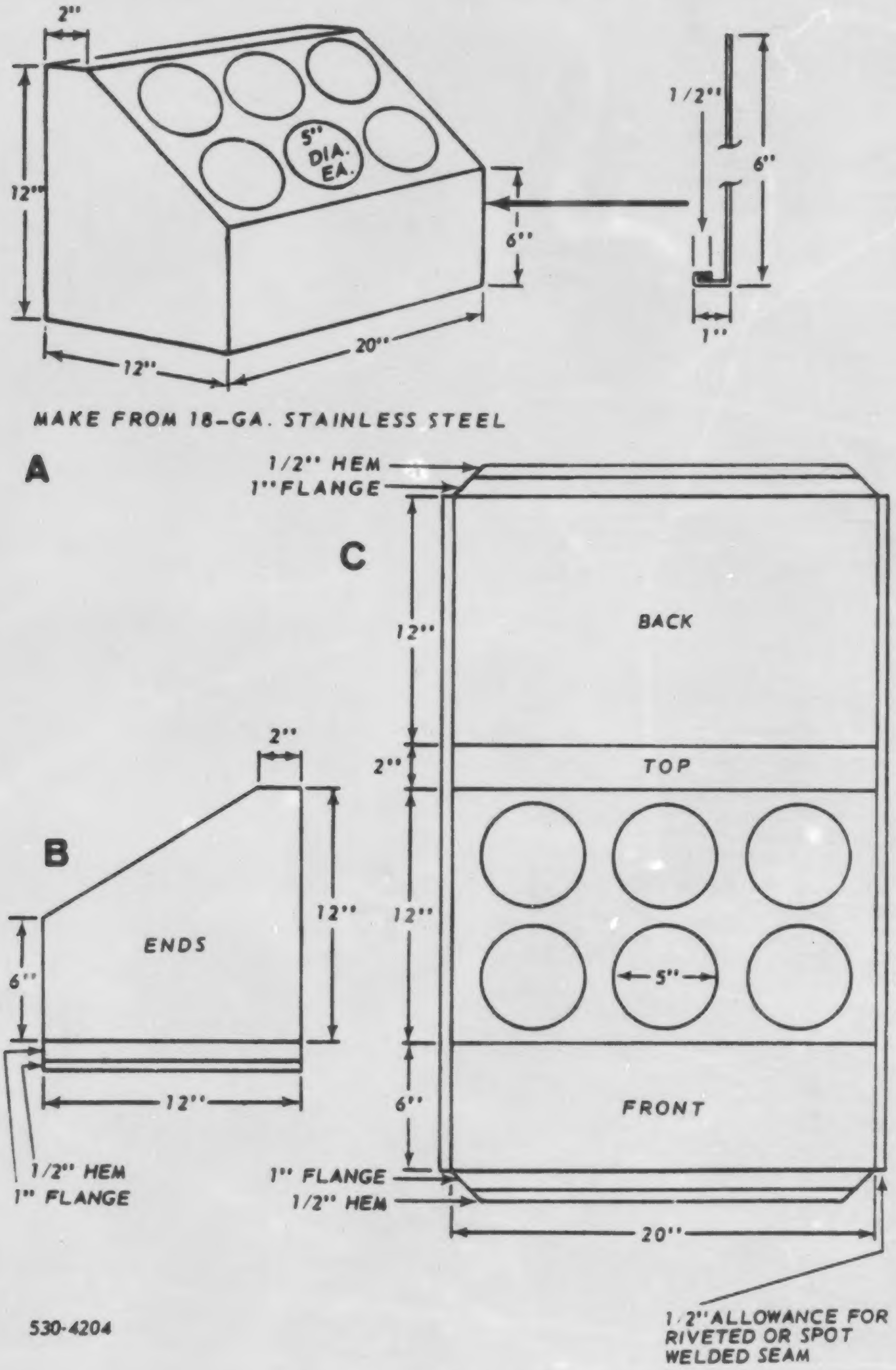

2"
12"
5" DIA. EA.
6"
12"
20"
1/2"
6"
1"
MAKE FROM 18-GA. STAINLESS STEEL
A
1/2" HEM
1" FLANGE
C
12"
BACK
2"
2"
TOP
B
12"
12"
ENDS
6"
5"
12"
6"
FRONT
1/2" HEM
1" FLANGE
1" FLANGE
1/2" HEM
20"
1/2" ALLOWANCE FOR RIVETED OR SPOT WELDED SEAM
530-4204

Figure 104. Holder for silverware.

below each half-round space for the rails. Each clip should have holes to accommodate ½-inch number 8 sheet metal screws. After the bracket is fabricated, fit it to the rails, drill 7/16-inch holes in the counter, and fasten the bracket plate to the counter with ⅜-inch corrosion-resistant bolts. Then secure the rails to the bracket with the self-tapping sheet metal screws.

15-15. **Replacing a Silverware Holder.** The silverware holder shown in figure 104 is made of 18-gage stainless steel and can be fabricated in the sheet metal shop. The dimensions from the old holder can be used to lay out the patterns on the adhesive paper covering of the stainless steel sheet. The pictorial view A of the illustration represents the old silverware holder to be replaced. Views B and C are the patterns you will need to cut from the metal. Each of the two end patterns has a 1-inch addition for the bottom flange and ½-inch allowance for the hem. The single patterns for the front, sloping top, top, and back have a ½-inch allowance on each side for the corner seams and additions and allowances on the ends for the flanges and hems. The 5-inch holes in the sloping top will accept the round baskets containing silverware. These baskets are factory made and may be plastic or stainless steel.

15-16. After layout is completed, cut the patterns with squaring shears and make the notches with straight snips. The pattern in view C is too large for the 5-inch holes to be cut out with ring and circle shears and too small to be cut with portable unishears. Therefore, the best choice of cutting equipment is aviation snips. Use the rotary punch to make starter holes inside each of the 5-inch holes to provide a starting place for the aviation snips. After all of the 5-inch holes are cut out, smooth the edges with a half-round, smooth, double-cut file and emery cloth. The other edges of the pattern should be smoothed in a similar manner.

15-17. The bends can be made with a cornice brake and a box and pan brake. To form the two end pieces, set the fingers of the box and pan brake to a width of 12 inches, bend the ½-inch hem 180°, and bend the flange 90°. To make the bends for the pattern in view C, first use the cornice brake to make the 90° bends for the seams along the ½-inch notched edges. Then use the box and pan brake (set for 20-inch-wide bends) to bend the 180° hems and 90° flanges at each end of the pattern. The last of the forming steps are the 90°, 30°, and 60° bends.

15-18. Assemble the three pieces of the silverware holder (with the end pieces on the inside of the ½-inch corner flanges) with Monel rivets or by welding. The final steps of assembly are to remove the adhesive paper from the completed silverware holder and to inspect for any remaining burrs along the edges.

15-19. **Repair of Broken Stainless Steel Welds.** Repair of a broken weld on stainless steel will involve the welding shop and the sheet metal shop. The welder will accomplish the necessary welding and the sheet metalworker will grind and polish the welded joints. First, clean the surface of the metal; if the crack *does not* run the full length of the weld, each end of the crack should be drilled to stop the break from moving further down the weld.

15-20. *Welding stainless steel.* The welder should use a welding rod with the same metal composition as that being welded. The crack should be tacked on each end and at about 2-inch intervals along the crack, and the weld should be staggered so that the metal surface will not become overheated and buckle. If the surface is overheated, the corrosion resistance of the stainless steel may become damaged, allowing the surface to corrode easily.

15-21. *Grinding stainless steel welds.* After the weld is completed and is cool, you will do the grinding, polishing, and buffing. For the grinding, use a portable grinder that has a hand wheel similar to that of a bench grinder. Hold the grinder with both hands, one near the grinding wheel and the other at the rear handle. Do the first grinding (rough cut) of the weld with a wheel of 20 to 24 (medium coarse) grit, and do the second grinding with a wheel of 40 to 60 (medium fine) grit. Be sure to stop the grinding before the weld bead is flush with the surface so that the polishing can be done. When using portable grinders, most workers want to use too much pressure on the grinder. This should *not* be done. Use a light and even pressure as the grinding wheel is moved along the weld. Allowing the wheel to remain in one spot too long causes the metal to overheat at that spot and may result in the metal's buckling. If the temperature at the spot being ground reaches 400° Fahrenheit, the metal will become tinted (turn blue). Cool the area that is being ground. Also, use a wet cloth to avoid overheating of the metal.

15-22. It is good shop practice to grind stainless steel with a wheel that has not been used on other metals; the foreign metals on the grinding wheels will contaminate the surface being ground. The wheel should be kept dressed so that you won't have a tendency to cant (tilt up or down) the wheel when grinding. When grinding, you can help keep the metal clean by applying adhesive paper on each side of the weld bead to protect the surface.

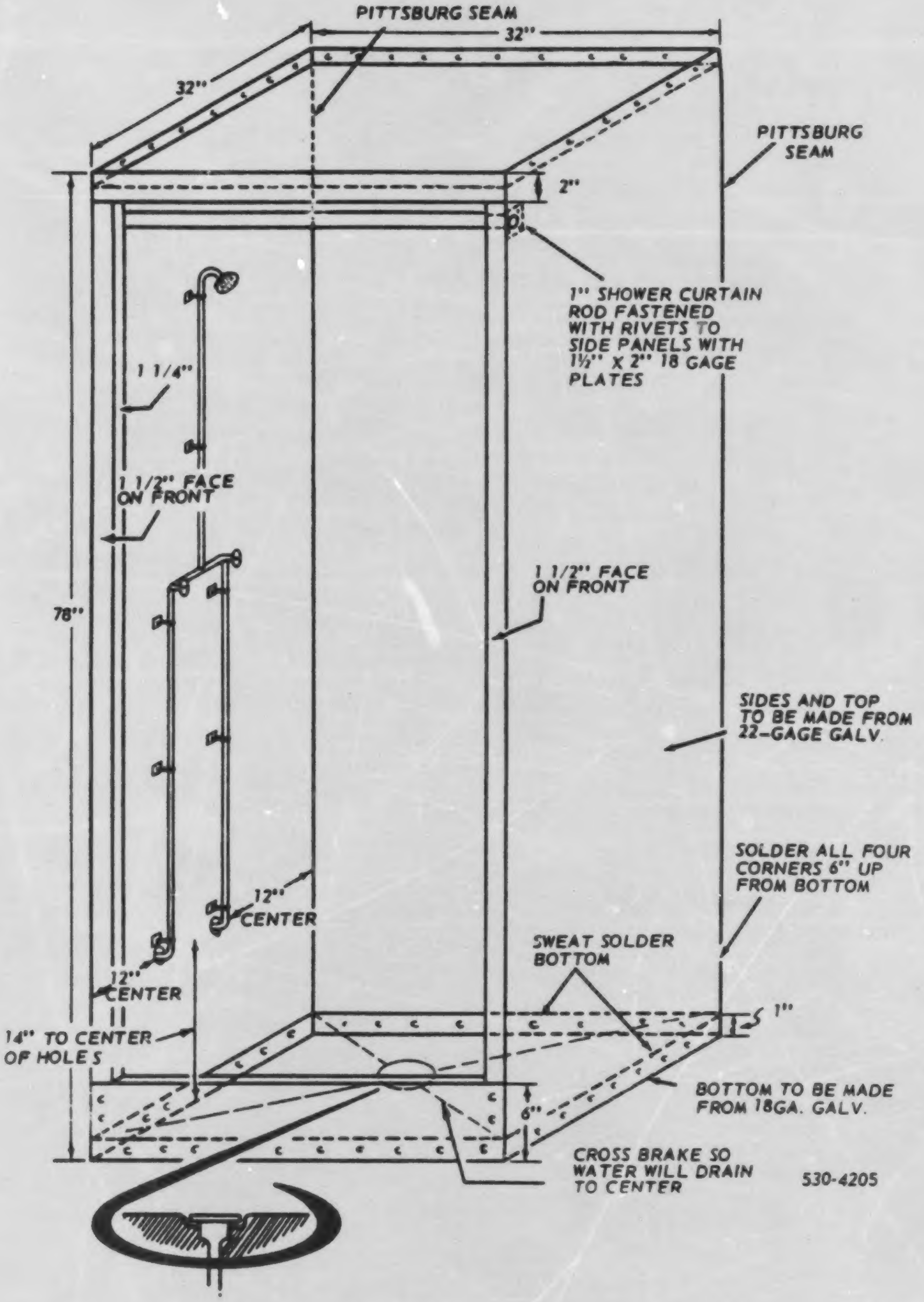
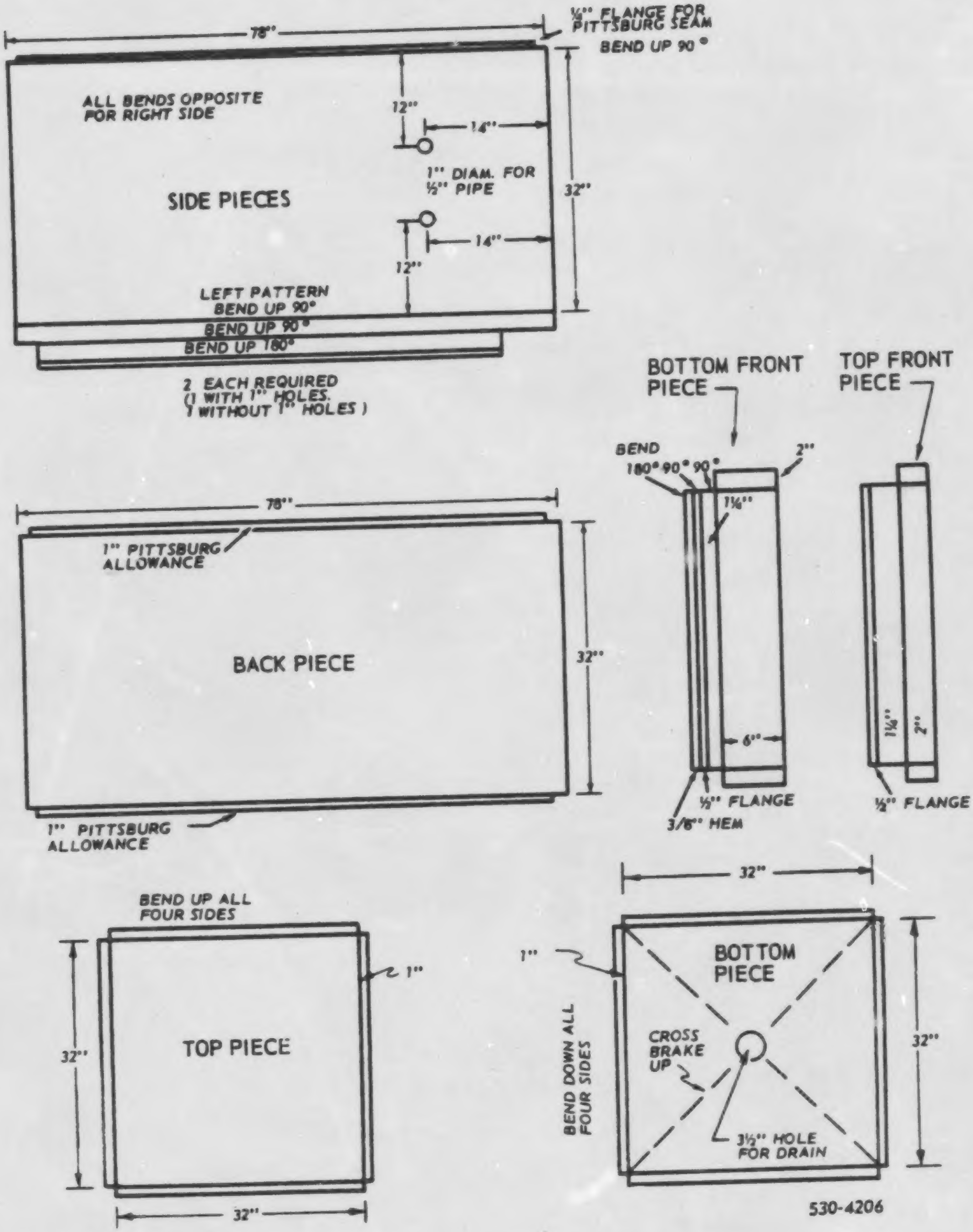

PITTSBURG SEAM
32"
32"
PITTSBURG SEAM
2"
1" SHOWER CURTAIN ROD FASTENED WITH RIVETS TO SIDE PANELS WITH 1½" X 2" 18 GAGE PLATES
1 1/4"
1 1/2" FACE ON FRONT
78"
1 1/2" FACE ON FRONT
SIDES AND TOP TO BE MADE FROM 22-GAGE GALV.
SOLDER ALL FOUR CORNERS 6" UP FROM BOTTOM
12" CENTER
12" CENTER
SWEAT SOLDER BOTTOM
1"
14" TO CENTER OF HOLES
BOTTOM TO BE MADE FROM 18GA. GALV.
6"
CROSS BRAKE SO WATER WILL DRAIN TO CENTER
530-4205

Figure 105. Shower stall.



¼" FLANGE FOR PITTSBURG SEAM
BEND UP 90°
78"
ALL BENDS OPPOSITE FOR RIGHT SIDE
12"
14"
1" DIAM. FOR ½" PIPE
32"
SIDE PIECES
14"
12"
LEFT PATTERN
BEND UP 90°
BEND UP 90°
BEND UP 180°
2 EACH REQUIRED (1 WITH 1" HOLES, 1 WITHOUT 1" HOLES)
BOTTOM FRONT PIECE
TOP FRONT PIECE
BEND 180° 90° 90°
2"
1⅛"
6"
½" FLANGE
3/8" HEM
1⅛"
2"
½" FLANGE
78"
1" PITTSBURG ALLOWANCE
BACK PIECE
32"
1" PITTSBURG ALLOWANCE
BEND UP ALL FOUR SIDES
1"
32"
TOP PIECE
32"
32"
1"
BOTTOM PIECE
BEND DOWN ALL FOUR SIDES
CROSS BRAKE UP
3½" HOLE FOR DRAIN
32"
530-4206

Figure 106. Patterns for a shower stall.

341

15-23. *Polishing stainless steel welds.* To start the polishing, you need to select a grinding wheel with a grit that will remove all the pits and scratches caused by the earlier grinding operation. A medium fine grit is often used first; but in some cases, when the surface is not too rough, you can use number 100 fine grit. The polishing is done until the surface is uniform and blemish-free. When changing grit size, the direction of grind should be changed also; this will help to eliminate the marks made by previous polishing. When starting to polish with very fine abrasive grits, you may want to use a lubricant, such as mutton tallow with stearic acid.

15-24. *Buffing stainless steel.* The buffing operation requires a buffing wheel that is flexible or soft near the outside edge. The wheel is made of layers of muslin sewn together. The surface of the metal should not be overheated when buffing or polishing. The first step in buffing will usually require a buffing compound. The final step of buffing, which is sometimes called coloring, is done with a clean wheel and a green chrome oxide preparation to get a very high luster (reflecting quality).

15-25. When polishing and buffing stainless steel, you will need to match the surrounding surface. The following guides will help you to obtain the desired finish:

- A number 4 finish may be obtained by using number 120 grit aluminum oxide applied on a soft wheel using a lubricant.
- A number 6 (tampico) finish is obtained from a number 4 finish by using a mixture of lubricating oil and powdered pumice (made into a paste) with a fine wire scratch wheel followed with a tampico fiber wheel.
- A number 7 finish can be obtained by buffing the surface with a very fine abrasive, such as white rouge, applied with a soft muslin buffing wheel.

16. Shower Stalls

16-1. Shower stalls are sometimes fabricated in the shop for a particular situation. However, most metal shower stalls are factory made and have porcelain or enamel finishes. Showers in most permanent structures are lined with ceramic tile. Occasionally, you will encounter a shower made from galvanized metal that may require repair where the metal has corroded or when a joint has broken. Fabrication of shower stalls consists of layout, cutting, forming, assembly, and installation. Suppose you are to fabricate a shower stall from galvanized sheet metal, like the stall shown in figure 105, for a decontamination station.

16-2. **Making Patterns.** To fabricate the shower stall, patterns of the pieces need to be developed. In this example, there is only one shower stall to fabricate, and the patterns can be developed on the sheet metal. First, make patterns like the ones in figure 106, including allowances and additions for the seams, flanges, and hems. Also include the notches and bending instructions. The bottom is to be made of 18-gage metal; the top, sides, and front pieces are to be made of 22-gage metal.

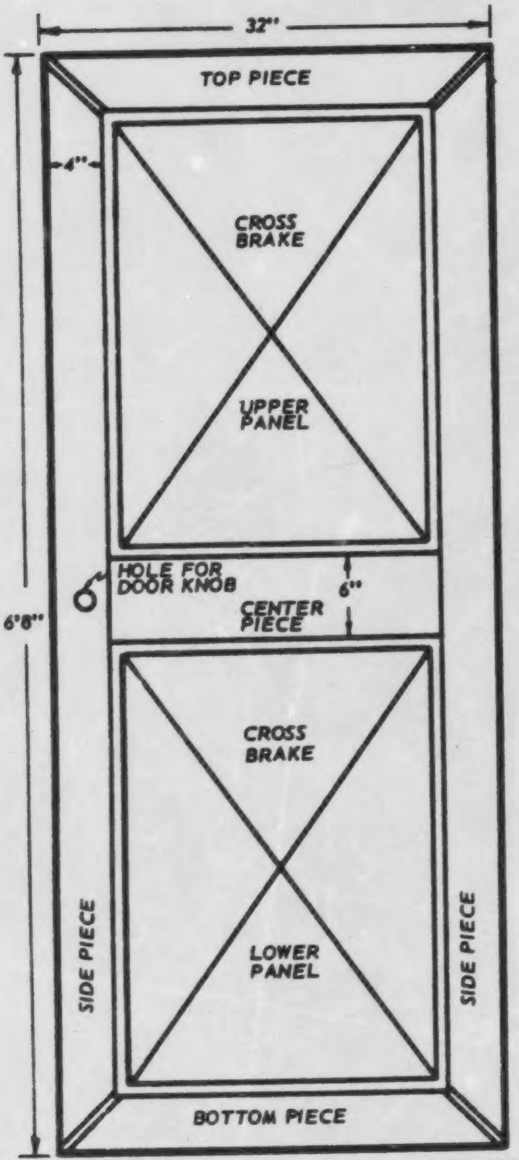
16-3. **Cutting and Notching.** Cut the outside edge of the pieces with the squaring shears. Make the notches with straight snips. Punch the 1-inch holes for the pipe with the rotary punch. Make the drain hole in the bottom piece by punching a starter hole with the rotary punch; then cut the 3½-inch hole with aviation snips.

16-4. **Forming.** Forming the pieces for the shower stall in figure 106 can be done on the Pittsburg lock forming machine, cornice brake, and box and pan brake. Run the back piece through the Pittsburg machine. Bend the side pieces, bottom front piece, and top front piece with the cornice brake. Bend the top and bottom with the box and pan brake. The bends are made as directed on the pieces in figure 106. Remember that two side pieces are needed, and the right side piece will be formed opposite from the left side piece.

16-5. The factory-made drain connection with strainer will have a flange, as shown in figure 105. Since the drain connection should be flush with the bottom piece for good drainage, ½-inch of the metal around the hole will need to be offset to accept the flange of the drain connection. To make this offset, measure the outside edge of the flange, and get a short piece of pipe with an inside measurement the same as the flange. Center the hole (in the bottom piece) over the short pipe, and use a tinner's riveting hammer to form (stretch the metal) the ½-inch offset by striking the edge that is around the hole. Continue this stretching process until the drain connection fits flush with the bottom of the shower piece. If you don't have a piece of pipe the correct size, prepare a form block for making the offset.

16-6. The curtain rod is made from 1-inch electrical conduit and is brazed to the two 1½" x 2" end plates. The length of the curtain rod, including the thickness of the end plates, should be the same as the inside measurements of the shower stall.

16-7. **Assembly.** The shower stall, shown in figures 105 and 106, is assembled after all of the pieces have been formed. Begin with the Pittsburg seams of the back and side pieces. Next, place the bottom and top in position and



NOTE:
1. COVER DOOR WITH 24-GAGE GALVANIZED SHEET METAL
2. USE 5/16" GROOVED SEAMS TO JOIN METAL
3. THE DOOR IS 1 3/8" THICK.

Figure 107. Door covered with metal.

temporarily fasten with C-clamps or vise grip pliers. Check the corners for squareness, reposition C-clamps as necessary, and then drill holes in the corners for tinner's rivets. After the corners have been riveted in place, lay out and make the other rivet holes. Install the rivets with the factory-made head on the outside of the shower stall. Clecos will be useful at two- or three-hole intervals to hold the metal in place. Next, install the front, top, and bottom pieces with rivets. Fasten the end plates of the curtain rod with rivets to the sides of the shower stall so that there is enough clearance for the curtain to slide freely.

16-8. Rivet the drain connection to the bottom of the shower stall. The rivet holes should be countersunk, and flat-headed Monel rivets should be used. Make certain there are no sharp edges. Sweat-solder the drain connections and the rivets to prevent leaks. All seams and rivets within 6 inches of the bottom of the shower stall should be sweat-soldered to prevent leaks.

16-9. **Installation.** Installation of the shower stall shown in figure 105 is not difficult, since it has been fabricated and assembled in the sheet metal shop. Handle it with care during transportation to the installation site. Installation will involve a plumber as well as a sheet metal worker. The plumber will install the water pipes and connect the drain connection. You will probably install the brackets that hold the water pipes in place.

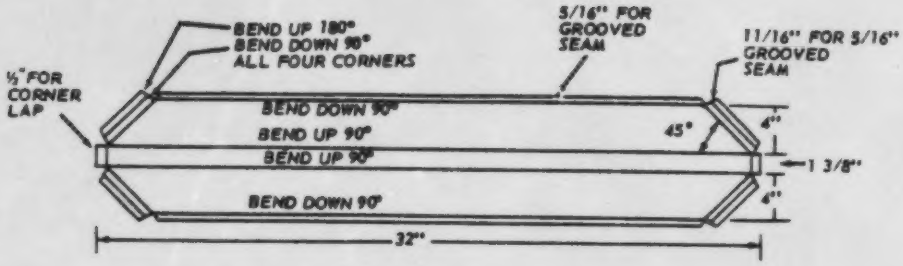
16-10. **Repair.** Repair of shower stalls usually consists of resoldering a seam or replacing the bottom. Resoldering a seam can be done on the job by cleaning the seam and sweating the solder into the seam.

16-11. To replace the metal bottom of a shower stall, you will need to take the entire assembly to the shop. This will involve the plumbers to disconnect the plumbing to the water supply and drain. If the bottom is riveted and soldered like the one shown in figure 105, the rivets will need to be drilled out and a soldering copper used to melt the solder in the seams so that the bottom piece can be pulled loose. After the bottom is free, the four side pieces should be cleaned (tinned). Next, make a new bottom piece like the old one and install it. After the new bottom is installed, riveted, and soldered, return the shower stall to the building for reinstallation. The reinstallation will again require that you and a plumber work together.

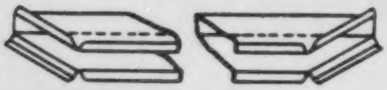
17. Fireproof Partitions and Doors

17-1. Earlier in this text, we discussed an automatic louver fire damper (fig. 46) for installation in heating and ventilating ducts. Now, we will discuss how doors and partitions are covered with sheet metal to prevent the spreading of flames in case of fire.

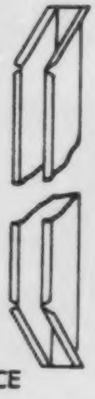
17-2. **Covering a Partition.** When partitions are to be covered with metal, the type and gage will be specified by the drawing or work order. The types of seams and method installation will be determined by you. For example, assume


BEND UP 180°
BEND DOWN 90°
ALL FOUR CORNERS
5/16" FOR GROOVED SEAM
11/16" FOR 5/16" GROOVED SEAM
½" FOR CORNER LAP
BEND DOWN 90°
BEND UP 90°
BEND UP 90°
BEND DOWN 90°
45°
4"
1 3/8"
4"
32"

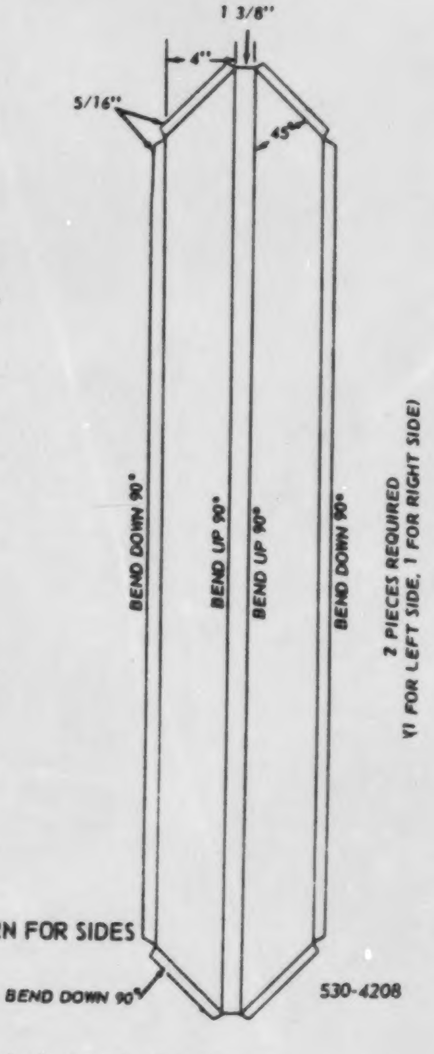
A PATTERN FOR TOP AND BOTTOM PIECES



B FORMED PIECE FOR TOP OR BOTTOM



C FORMED PIECE FOR SIDE


1 3/8"
4"
5/16"
45°
BEND DOWN 90°
BEND UP 90°
BEND UP 90°
BEND DOWN 90°
2 PIECES REQUIRED
(1 FOR LEFT SIDE, 1 FOR RIGHT SIDE)
BEND DOWN 90°
530-4208

D PATTERN FOR SIDES

Figure 108. Top, bottom, and side pieces for door covering.

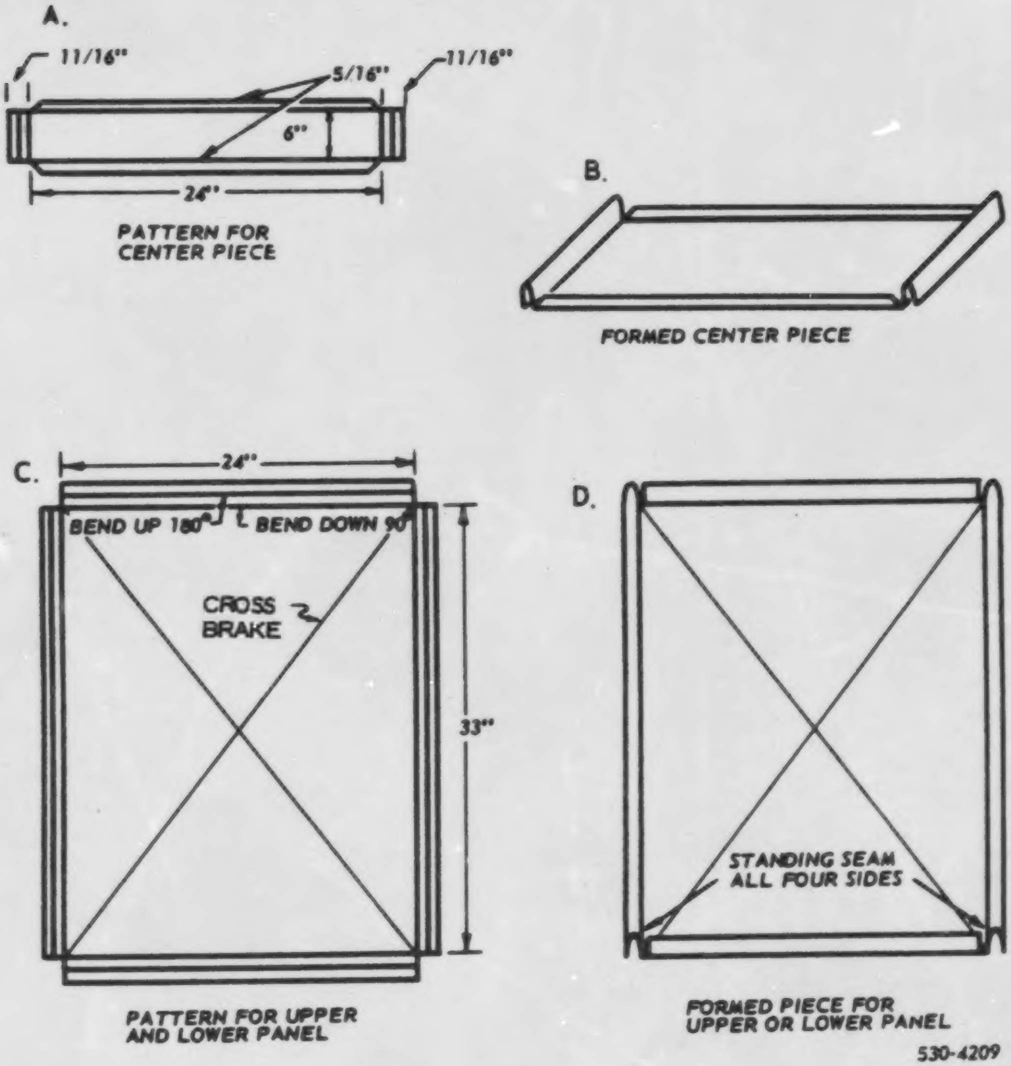

A.
11/16"
5/16"
11/16"
6"
24"
PATTERN FOR CENTER PIECE
B.
FORMED CENTER PIECE
C.
24"
BEND UP 180°
BEND DOWN 90°
CROSS BRAKE
33"
PATTERN FOR UPPER AND LOWER PANEL
D.
STANDING SEAM ALL FOUR SIDES
FORMED PIECE FOR UPPER OR LOWER PANEL
530-4209

Figure 109. Panels and center pieces for door covering.

that a wall partition is to be covered with metal. First, measure the wall; then locate the studs so that you can determine where seams will be located and the number of sheets needed to cover the wall. As the measurements are taken and locations of the wall studs determined, make a sketch for reference purposes.

17-3. It is best to locate the seams so that the studs can be used to attach the metal. If you are using grooved seams, a nail can be driven through the metal and into the stud. When using grooved seams, be sure that the last edge is turned up to allow the next sheet to be joined and locked in place. If the seams are joined at the studs, the stud will serve as a backer when setting the seam with a mallet.

17-4. Another means of joining the metal for a fire partition is with a cap strip. This is done in a manner similar to that used for installing the cap strip on a serving line counter, as shown in figure 101. The sheets are butted together at the center of the studs. Nail the cap strips over the butt joint for the entire length of the joint.

17-5. **Covering a Fire Door.** Covering a fire door with metal is somewhat like covering a partition. Seams are used to join the metal, and the door must be measured for length, width, and thickness. The thickness measurement is needed, since fire doors are covered on both sides. Figure 107 shows a door with dimensions and instructions for covering with sheet metal. The metal is joined with grooved seams, and the panels are cross broken to stiffen the metal.

17-6. **Pieces for sides, bottom, and top.** The sequence for fabricating and installing the metal pieces to cover a fire door is somewhat different from that for other sheet metal jobs. First, the patterns for the top, bottom, and sides are developed, cut, and notched, as shown in views A and C of figure 108. The pieces are formed into shapes on the cornice brake (like views B and D), except where the seam allowances are made on the 45° corners and the lap tab on the top and bottom pieces. These tabs can be formed with the hand seamer after other bends are made on the cornice brake. Notice that the seam allowances at the ends of the top and bottom pieces include two widths of a 5/16-inch grooved seam plus the metal thickness. Notice also that one allowance is bent 90°, and the other is bent 180°. When forming these seam allowances with the hand seamer, make only the 90° bends, as shown in view B of figure 108. The 180° bends will be completed later when the corners of the top, bottom, and side pieces are installed. Figure 13 shows how a grooved seam is made from a standing seam. This is how we will join the corners.

17-7. Now that the pieces are formed, install them on the door. Start with the top and bottom pieces, and place them over the ends of the door. You will notice a crease along the 1⅜-inch side of each piece which was made by the cornice brake when the second 90° bend was bent. This crease can be removed with a mallet; the edge of the door will act as a backer. After the pieces are fitted, use nails to hold them in place. The nails should be placed close to the standing edge so that the heads will be concealed when the grooved seams are completed. When you turn the door over on the worktable to nail the opposite side, use four blocks of wood about 1-inch thick and 3 to 4 inches long as spacers (one on each corner) so the weight of the door will not damage the standing edges of the pieces. After the top and bottom pieces are in place, bend down the ½-inch corner tabs 90° with a mallet.

17-8. The side pieces are also ready for installation. When placed on the door, the creases on the 1⅜-inch side can be straightened the same as the top and bottom pieces were. Butt the seam allowance flanges of the side pieces snug against the seam allowance flanges of the top and bottom pieces. This is the beginning of the standing seam. After the sides have been nailed in place (as you did for the top and bottom pieces), the outside 5/16-inch allowance is ready to be bent 180° over the shorter flange to make a standing seam. After starting these folds with the hand seamer, use a tinner's riveting hammer and dolly to complete the 180° fold. Do this on all four corners on both sides of the door, and be sure you use the block spacers each time the door is turned. Do not fold the standing seams into grooved seams at this time; wait until the center panels are installed.

17-9. *Center pieces.* With the sides, bottom, and top pieces in place the next step is to make the center pieces. To do this, measure the distance between the standing edges (seams) of the side pieces. This distance is the length of the center pieces. Use this measurement and make a pattern like view A in figure 109, which in this example will be 6″ x 24″. Two of these patterns are needed, one for each side of the door. You should measure them separately to make sure of a good fit.

17-10. After the two center patterns are cut and notched, they should be formed like view B in figure 109 with a box and pan brake. Notice that each end of the pieces has a pocket for a standing seam that will be joined with the flanges of the side pieces.

17-11. To install the center pieces, locate the horizontal centerline on each side of the door and install the pieces. Fit the pockets of the standing seam (of the center piece) over the flanges of the side pieces. Use a tinner's riveting hammer and a dolly to tighten the pockets of the standing seam so that the center pieces will stay in place while measurements for the other panels are made.

17-12. *Upper and lower panels.* The panels should be measured separately so that a good fit will be obtained. The length and width of each panel are measured between the flanges of the pieces already installed on the door. For this example, view C in figure 109 shows the dimensions to be 24″ x 33″. The next step is to develop the pattern, including seam allowances, notching, and bending instructions.

17-13. Once these patterns for the upper and lower panels are developed, they should be cut out with the squaring shears and the notches cut with straight snips. Make the bends with the box and pan brake until the panels look like view D in figure 109. Best results will be obtained if the 180° folds are made before the 90° folds.

17-14. After the panels are formed, they are ready to be joined to the other pieces. To do this, place the pockets of the standing seams over the flanges of the pieces already nailed to the door, and tighten the pockets with a tinner's riveting hammer and dolly. After tightening, the standing seams are ready to be formed into a grooved seam, such as that shown in figure 13.

17-15. All of the standing seams on the door are now assembled and are ready to be folded over and made into grooved seams. Use a hand seamer to bend the standing seams as far as possible; then use a mallet to flatten them completely down. Figure 13 shows how the seams will appear when flattened. The next step is to use a hand groover, as shown in figure 11, and groove all of the seams on both sides of the door.

17-16. To make a smooth finish, solder the corners of the door where the tabs lap inside and at the corners where the panel seams and 45° seams meet. Use 2-pound fire-heated soldering coppers and 50/50 solder. Clean the surfaces with a wet cloth when the soldering is completed. After the door is covered, you will need to cut slots and holes for the hinges and door knob. You will work with a carpenter when doing this. Cut the slots for the hinges with a sharp ½-inch cold chisel and cut the holes for the door knob with a hole saw.

17-17. **Repair.** Repair of fire doors or partitions is sometimes necessary because of damage. Usually repairs are made by patching or replacement of a piece. Patching is often done by cutting out the damaged metal and nailing a patch over the area. Suppose a sliding fire door in a warehouse has a damaged area that measures 4 inches long and 3 inches wide. First, cut out the damaged area. Aviation snips make this work satisfactory if the metal is not too tight; if the metal is tight, a cold chisel may be required. Next, cut out a patch that will have a ½-inch overlap all around the area where the metal was

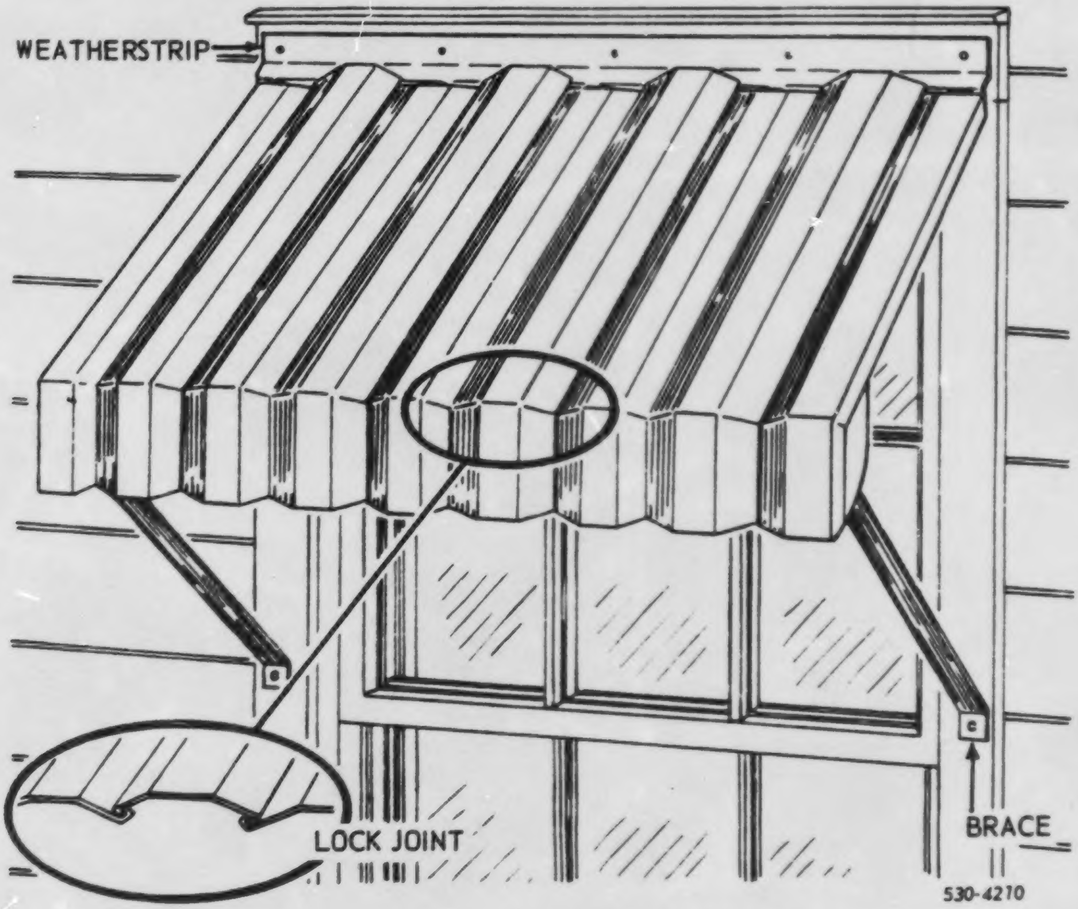


Figure 110. Metal awning over a window.

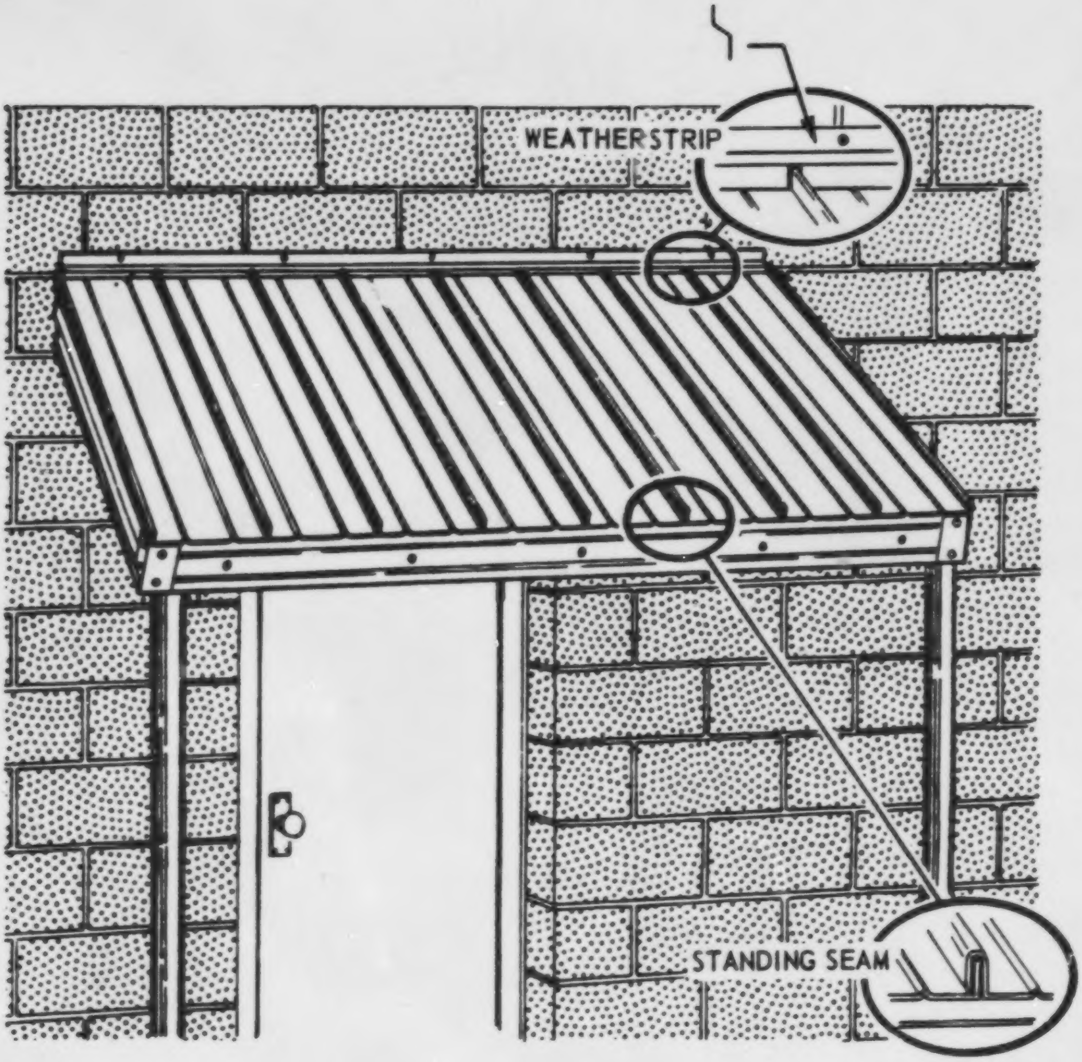


Figure 111. Metal canopy over a door.

removed. Make the patch from the same gage metal the door is covered with; cut the patch to size and round off tne corners. You may want to punch holes in the patch for the size of nail you are using to fasten the patch. After the patch is prepared, nail it over the area where the metal was removed.

17-18. When a large area has been damaged, a door or partition that is seamed together, such as a fire door, may be repaired by removing and installing a replacement piece. To do this, it is necessary to open the seams and remove the damaged part. A duplicate piece is made to replace the metal that was removed.

18. Awnings

18-1. Metal awnings are usually installed over windows to keep out heat or prevent damage to the screen or glass. It is not likely that you will fabricate awnings because they are usually purchased as factory-made assemblies. Your job will usually consist of installation and repair. Awnings, like the one in figure 110, are usually installed over windows and are made of interlocking aluminum panels. The brace on this awning is made of round tubing, but others may be made of square tubing or angle iron. The braces are adaptable for different installations.

18-2. **Assembly.** Awnings are assembled in accordance with the manufacturer's instructions. Normally, the assembly procedure starts at one end of the awning, where you lock the panels together. As the panels are put into place, bolts and nuts are used to fasten them to the frame. After the awning is completely assembled, it is ready to be installed on a building.

18-3. **Installation.** To install the awning over a window, as shown in figure 110, the center of the weatherstrip and the window must be determined so that the awning will extend the same distance on each side of the window. The holes for the screws are located by marking them as the strip is held in place and level with the window. After the holes for the weatherstrip are drilled, apply the calking compound to the back side of the weatherstrip and fasten the strip to the wall with screws. Attach the awning to the weatherstrip (with nuts and bolts); then drill holes for the braces and fasten the braces to the wall with screws.

18-4. If the awning, shown in figure 110, is to be installed in a building of masonry construction, a masonry drill will be needed to make holes for expandable sleeves. The expandable sleeves fit into the holes and act as anchors for the screws so that the weatherstrip and braces can be fastened to the wall. The weatherstrip

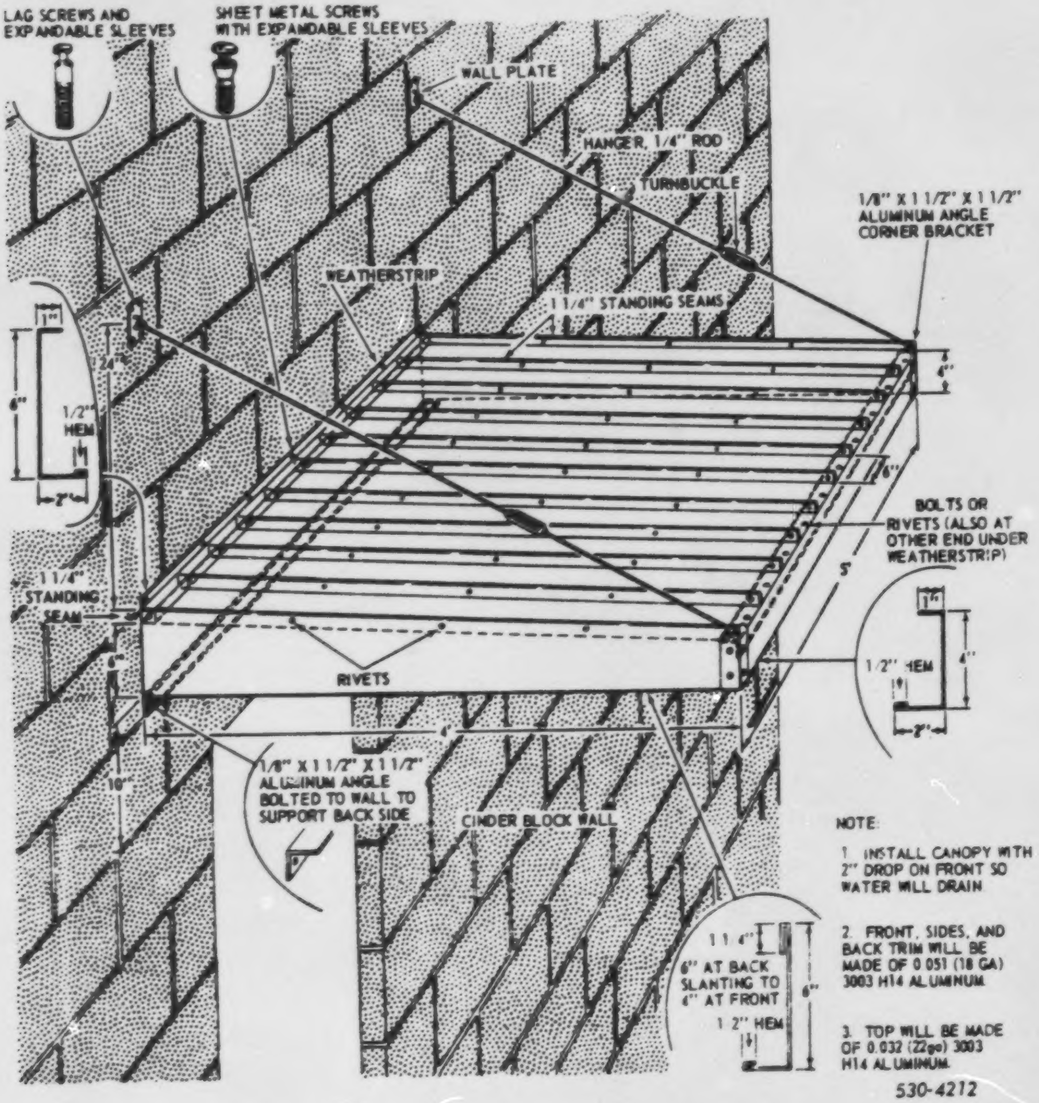

LAG SCREWS AND EXPANDABLE SLEEVES
SHEET METAL SCREWS WITH EXPANDABLE SLEEVES
WALL PLATE
HANGER, 1/4" ROD
TURNBUCKLE
1/8" X 1 1/2" X 1 1/2" ALUMINUM ANGLE CORNER BRACKET
WEATHERSTRIP
1 1/4" STANDING SEAMS
1"
6"
24"
1/2" HEM
2"
4"
6"
BOLTS OR RIVETS (ALSO AT OTHER END UNDER WEATHERSTRIP)
5'
1 1/4" STANDING SEAM
6"
RIVETS
1"
1/2" HEM
4"
2"
4'
10"
1/8" X 1 1/2" X 1 1/2" ALUMINUM ANGLE BOLTED TO WALL TO SUPPORT BACK SIDE
CINDER BLOCK WALL
1 1/4"
6" AT BACK SLANTING TO 4" AT FRONT
6"
1 2" HEM
NOTE:
1. INSTALL CANOPY WITH 2" DROP ON FRONT SO WATER WILL DRAIN
2. FRONT, SIDES, AND BACK TRIM WILL BE MADE OF 0.051 (18 GA) 3003 H14 ALUMINUM
3. TOP WILL BE MADE OF 0.032 (22ga) 3003 H14 ALUMINUM
530-4212

Figure 112. Metal canopy supported by hangers.

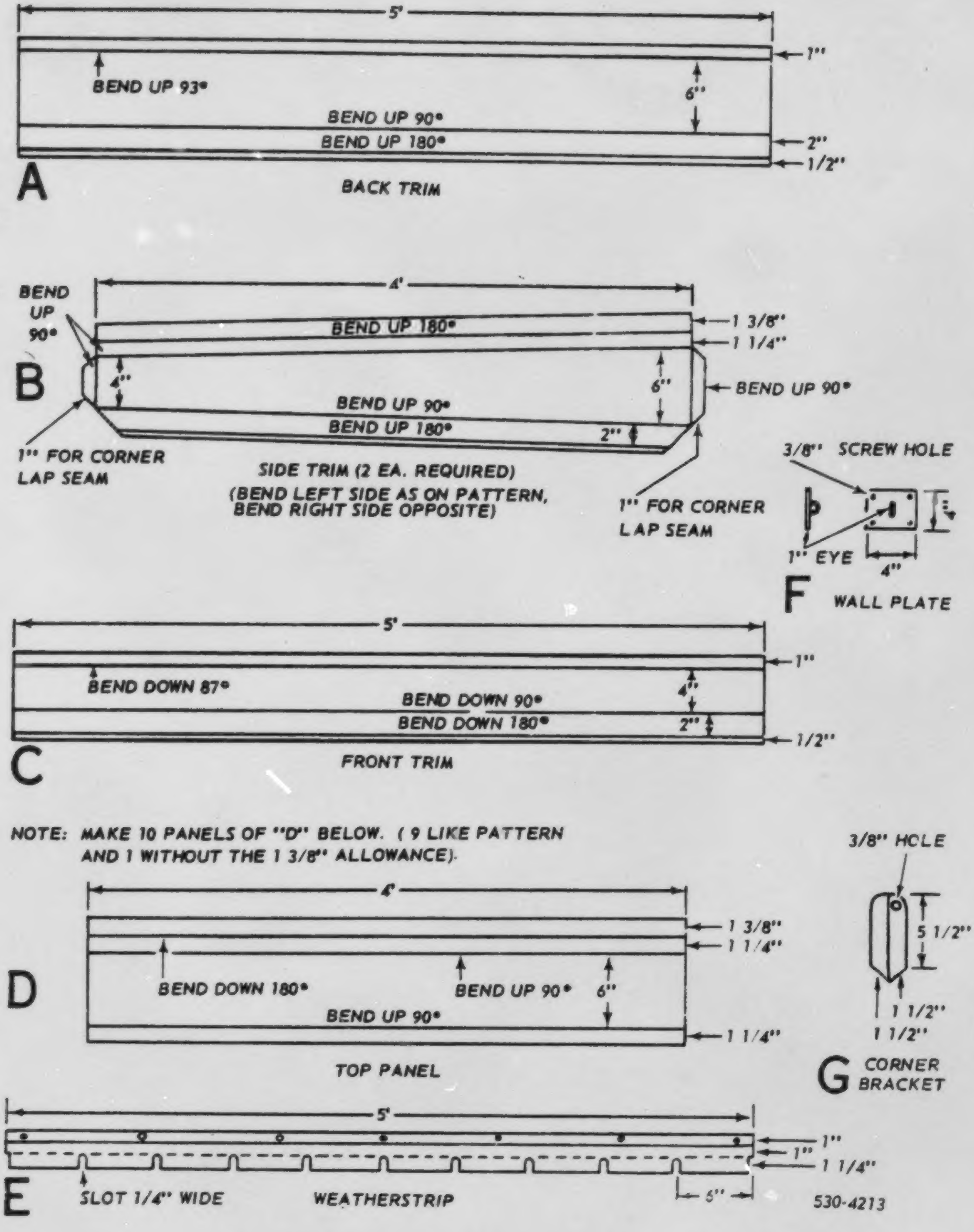

5'
1"
BEND UP 93°
6"
BEND UP 90°
BEND UP 180°
2"
1/2"
A
BACK TRIM
BEND UP 90°
4'
1 3/8"
BEND UP 180°
1 1/4"
B
4"
6"
BEND UP 90°
BEND UP 90°
BEND UP 180°
2"
1" FOR CORNER LAP SEAM
SIDE TRIM (2 EA. REQUIRED)
(BEND LEFT SIDE AS ON PATTERN, BEND RIGHT SIDE OPPOSITE)
1" FOR CORNER LAP SEAM
3/8" SCREW HOLE
1" EYE
4"
F
WALL PLATE
5'
1"
BEND DOWN 87°
4"
BEND DOWN 90°
BEND DOWN 180°
2"
1/2"
C
FRONT TRIM
NOTE: MAKE 10 PANELS OF "D" BELOW. (9 LIKE PATTERN AND 1 WITHOUT THE 1 3/8" ALLOWANCE).
4'
1 3/8"
1 1/4"
D
BEND DOWN 180°
BEND UP 90°
6"
BEND UP 90°
1 1/4"
TOP PANEL
3/8" HOLE
5 1/2"
1 1/2"
1 1/2"
G
CORNER BRACKET
5'
1"
1"
1 1/4"
E
SLOT 1/4" WIDE
WEATHERSTRIP
5"
530-4213

Figure 112. Patterns for a metal canopy supported by hangers.

350

will need to be calked so that water won't run behind it.

18-5. **Repair.** Awnings are repaired by replacing panels or patching. Most repair will be done because of damage done by wind or hail. When an awning is damaged, it should be inspected to determine what repairs are necessary; sometimes it may need to be completely replaced.

18-6. Suppose that the awning in figure 110 has been damaged; upon inspection it is found that one brace and one end panel need replacing. The awning should be removed and taken to the shop. To do this, remove the screws that anchor it to the wall. As the awning is being taken down, determine whether any screws will need to be replaced during reinstallation. When the awning is taken to the shop, disassemble the parts that need replacing and take the necessary measurements.

18-7. Lay out the pattern for the replacement panel, using the same type of metal and the same gage as the old panel, and then cut out the pattern with a suitable cutting machine. Since the panel has straight sides, the squaring shears will be suitable for the straight cuts. Straight snips can be used for notching the metal where notching is necessary.

18-8. The brace is made of tubing that is flattened and bent on the ends. To make a replacement, cut tubing to the desired length with a hand hacksaw, power horizontal bandsaw, or power hacksaw. Flatten the ends by placing the tubing on a solid surface such as an anvil and striking the tubing with a ball-peen hammer or tinner's riveting hammer. Turning the tubing over several times will enable you to do a good job of flattening the tubing. After flattening, drill holes in each end so that the brace can be fastened to the awning and wall, and attach the brace.

18-9 **Reinstallation.** Reinstallation of the awning will require fastening the weatherstrip and braces to the wall. Any fasteners that were damaged should be replaced. Some of the holes may need larger screws or bolts to fasten the awning to the wall. As the installation is done, check the awning to see that it is level across the top and use a sealant behind the weatherstrip. Except for drilling holes, the reinstallation procedure is the same as installation of a new awning.

19. Canopies

19-1. Metal canopies are similar to metal awnings but are usually larger and are installed over doors or entrance walks. Repair and fabrication procedures for canopies are also similar to those for awnings. Canopies are usually made of aluminum panels joined with standing seams or lap joints. Figure 111 shows a factory-made canopy installed over a door. It has standing seam roof panels with metal trim on the sides. It is supported by two corner posts made of 2-inch aluminum tubing at the front and is fastened to the wall at the back. The canopy has a weatherstrip that extends 1 inch over the top panels to prevent water from leaking between the walls and back of the canopy. A factory-made canopy such as this is assembled and installed according to the instructions packed with the pieces.

19-2. Canopies can also be fabricated in the shop. Suppose that you have a work order to make and install a canopy such as that illustrated in figure 112. Notice that this canopy has a standing seam paneled roof and hangers to support the front. The bottom of the canopy sides will be 90° to the wall and level; the panels will have a 2-inch drop from the rear to the front. Fabrication of a canopy is similar to other sheet metal fabrications and will involve pattern layout, cutting, notching, forming, assembly, and installation.

19-3 **Pattern Layout.** Pattern layout for the canopy involves developing patterns like the ones shown in figure 113. The back trim pattern in view A is made 9 inches wide plus allowance for a ½-inch hem. The shape of the back trim is shown in one of the detail views in figure 112.

19-4. The two side patterns (view B of fig. 113) are developed so that the face of the trim will be 6 inches wide at the back and 4 inches wide at the front. Notice that each end has 1 inch for the corner lap seams. The bottom edge has an allowance for a ½-inch hem, and the top edge has an allowance for the pocket of a 1¼-inch standing seam.

19-5. The front trim pattern shown in C of figure 113 has a face 4 inches wide and allowances for a ½-inch hem on the bottom edge and 1 inch on the top edge for fastening to the top panels.

19-6. The pattern for the nine top panels in D of figure 113 is 6 inches wide plus allowances for the pocket of a 1¼-inch standing seam on one edge and the flange for a 1¼-inch standing seam on the other edge. Notice the instructions with the patterns.

19-7. The weatherstrip in view E of figure 113 is made into a Z-shape (see fig. 112) that measures 1" x 1" x 1¼" and is 5 feet long. The 1¼-inch allowance has slots ¼ inch wide and 1¼ inch long cut at 6-inch intervals. The wall plate (F of fig. 113) is 4 inches square and [illegible] hook shape [illegible]

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The eye is welded to the plate, and four 5/16-inch screw holes are drilled for ¼-inch screws. The corner brackets (G in fig. 113) are made of ⅛" x 1½" x 1½" angle iron 5 inches long with a ⅜-inch hole for the ¼-inch hanger rod.

19-8. **Cutting and Notching.** Cutting and notching of patterns A through D (fig. 113) can be done on the squaring shears and with straight cut snips. Pattern E can be cut with the squaring shears and notched with straight snips; the slots are made by using the rotary punch and straight snips.

19-9. The corner brackets and wall plates can be made by the welding shop, as shown in G and F of figure 113. The straight cuts are made with the horizontal bandsaw, power hacksaw, or hand hacksaw. The rounded end of the corner bracket is cut on the throatless shears and filed smooth; then the holes are drilled. The ⅜-inch hole should be drilled at least 1¼ inch from the top edge. Remember to make two wall plates and right and left corner brackets. The eye of the wall plate is made by welding a piece of ¼-inch rod (bent into a U-shape) to the plate. The eye should be approximately 1 inch in diameter.

19-10. **Forming.** Pieces A through E for the canopy are bent on the cornice brake according to instructions on the patterns. The only bends that are made with a mallet are the 90° bends for the corner lap seams on the ends of the side pieces in B.

19-11. **Assembly.** The canopy shown in figure 112 is assembled by first connecting the standing seams of the top panels. Notice in view D of figure 113 that the 10th panel has two flanges instead of one flange and a pocket. When installing the top panels, this 10th panel is installed last (on the right side of the canopy as viewed from the front). Next, the front and back trim pieces are positioned, and the panels are riveted (or bolted) as shown in the illustration. Rivet holes are drilled as needed, and aluminum rivets or cadmium-plated bolts are used. The side pieces are slant notched on the 2-inch flange so that the corners of the assembled canopy will have a mitered appearance like the corners of the hood discussed earlier in this text. When the front corners are squared, the corner braces are installed and riveted (or bolted). The last step of assembly is to install rivets at 12-inch intervals along the standing seams.

19-12. **Installation.** To install the canopy shown in figure 112, drill holes in the cinder block wall for the expandable anchor sleeves which hold the screws. The sleeves may be made of lead, plastic, or wood and are sometimes called anchor plugs or shields. When placed in the hole, the sleeve expands when the screw is inserted and tightened, making a secure anchor for the screw. In this example, the bottom of the canopy is installed 10 inches above the door. The canopy is bolted to a 5-foot aluminum angle piece (⅛" x 1½" x 1½") which is anchored to the wall with ¼-inch lag screws and expandable sleeves. Use the angle piece as a template to locate the holes to be drilled. Use a masonry drill or star drill to make seven ½-inch holes. Now, the angle piece can be securely fastened to the wall with the lag screws and expandable sleeves. The two wall plates are also anchored to the wall, 30 inches above the angle piece, with ¼-inch lag screws and expandable sleeves.

19-13. After the aluminum angle piece and wall plates are mounted, install the weatherstrip with expandable sleeves and number 10 sheet metal screws. Calking compound should be placed on the back side of the weatherstrip for a seal. Install the weatherstrip on the wall above the top of the angle piece so that the distance between the bottom of the slots in the weatherstrip and the top of the angle brace is about 7½ inches. This will allow the standing seams of the top panels to slide into the slots and the bottom of the back trim to rest on top of the angle piece.

19-14. Before raising the canopy, hook the hangers into the eyes of the wall brackets. The task of raising the canopy into position will probably require two or three workers, depending on the situation. If a scaffold is being used, the canopy can be placed on the scaffold and then positioned at the desired angles.

19-15. When the hangers are hooked, the canopy is leveled by adjusting the turnbuckles. After leveling, holes are drilled through the aluminum angle piece and bottom edge of the back trim piece, and the two pieces are bolted together.

19-16. **Repair.** Repair of canopies, as shown in figure 112, is somewhat similar to the repair of awnings. Usually, the damage is caused by hail or wind. Suppose the fourth panel from the right side of the top (as viewed in the illustration) has a 1-inch hole in it. To make the repair, cut out the damaged section, and cut out two patches of the same type and gage of metal as the awning. The patches should overlap 1 inch all around the hole. One of the patches is for the top, and one is for underneath the panel. The top patch will need to be sealed when the patches are placed on the panel so that zinc chromate tape or roll-type calking can be used; if these are not available, you can use caulking compound from a tube and spread it with a putty knife.

19-17. The thickness of the patches will determine the size of rivets to use for the repair. Once they are determined, one patch can be punched or drilled and used as a template to punch the other patch. A hand dolly, rivet set, Clecos, Cleco pliers (forceps), tinner's riveting hammer, portable electric drill, extension cord, twist drill, and aluminum rivets will be needed.

19-18. To install the patch, apply the sealant on the top of the panel around the hole. Lay the top patch over the hole so that a 1-inch lap is obtained around the hole. Drill the holes and install the bottom patch in alignment with the other holes. The patches can be held in place with the Clecos while the holes are drilled and the rivets installed. After all the rivets have been installed, remove any excess sealant around the patch so that a neat job will be obtained.

19-19. For a second example of canopy repair, suppose the second panel from the right side of the canopy shown in figure 112 needs replacing. The old panel is removed by removing the weatherstrip first. Next, the rivets on both sides of the standing seams should be drilled out. The screws on the second panel and the panels on each side of the second panel will need removing. This is necessary so that the panels can be raised to remove the second panel for the standing seams.

19-20. Once the screws are removed, the old panel can be slipped out of the standing seams. A panel like the one shown in D of figure 113 should be made for a replacement. After fabrication, place the new panel into position and connect the standing seams. After the new panel is in place, drill the holes for fastening to the flanges of the back and front trim pieces. Replace the rivets that were drilled out of the standing seam. Since the weatherstrip has been removed, the old calking should be removed and new calking applied. The weatherstrip is then positioned and refastened to the wall to complete the panel replacement job.

CHAPTER 6

Fabrication, Installation, and Repair of Roofing, Flashing, Gutters, and Downspouts

IN THIS CHAPTER we will discuss the fabrication, installation, and repair of roofing, flashing, gutters, and downspouts; these are available in different shapes and designs. They may be made of galvanized iron, aluminum, or copper. Metal flashing is used with all types of roofing (metal, shingle, and asphalt) to weather proof the joints, valleys, eaves, gables, and ridges. Gutters are installed under the eaves of buildings to collect rainwater from the roofs, and downspouts are the vertical pipes which carry the rainwater from the gutters to the ground.

2. The discussions include types of roofing, seams, and special tools; types of flashing, such as valley, fascia, gable, eave, ridge, and base; and components of gutters and downspouts.

3. The knowledge you gain from this chapter will help you meet the requirements of your Job Training Standard and will enable you to do better work when assigned jobs that involve roofing, flashing, and downspouts. The examples discussed in this chapter are similar to the jobs you will be expected to do as a sheet metalworker.

20. Metal Roofing

20-1. Metal roofing is made of different kinds of metal, such as copper, aluminum, and galvanized iron; these metals were discussed in Volume 1. Let's briefly review some of the characteristics of metal that are important when using metal for roofing, flashing, gutters, and downspouts.

20-2. Copper, aluminum, and iron expand when they are exposed to heat and contract when exposed to cold. An 8-foot sheet of copper will expand or contract as much as $\frac{9}{64}$ inch; aluminum will expand or contract as much as $\frac{3}{16}$ inch; and iron as much as $\frac{3}{32}$ inch. Thus, you can see that seasonal effects will have some bearing on the installation of metal roofs. For example, when installing metal roofs in cold weather, provisions should be made for expansion but very little for contraction.

20-3. Because of galvanic action that occurs when dissimilar metals come in contact with one another, you should avoid joining different metals. If they should require joining, a layer of waterproof building paper, a layer of asphalt-saturated felt, or a coating of asphalt paint should be used between the sheets.

20-4. **Types of Metal Roofing Material.** Copper, aluminum, and galvanized iron are the metals often used for roofing material to cover buildings. These types may be purchased in different shapes, such as those shown in figure 114. Flat sheets are also used to cover roofs but are not illustrated.

20-5. *Copper sheets.* Copper sheets used in roofing are usually 0.022 inch thick. Copper sheet thicknesses are designated by ounces per square foot; therefore, 0.022 inch thick is 16-ounce copper. Copper roofs are usually installed with grooved (flat seams, batten seams, or standing seams with cleats fastened to the roof deck and formed into the seam. One advantage a copper roof has is that it lasts longer because of its resistance to corrosion. When new copper sheets are exposed to the atmosphere, a coating of oxide forms which is called *patina.* It aids in making the surface resistant to further corrosion. Fasten copper with nails, screws, or bolts made of brass or bronze.

20-6. *Aluminum sheets.* Aluminum sheets used in roofing may be flat, corrugated, or double rib. The corrugated and double-rib aluminum sheets are stronger than flat sheets or 5 V-crimp and are used often to cover roofs that do not have a solid deck underneath. The corrugated and double-rib sheets have other advantages over flat sheets, because they increase the discharge of water from the roof and the seams do not require soldering. Fasten aluminum with nails,

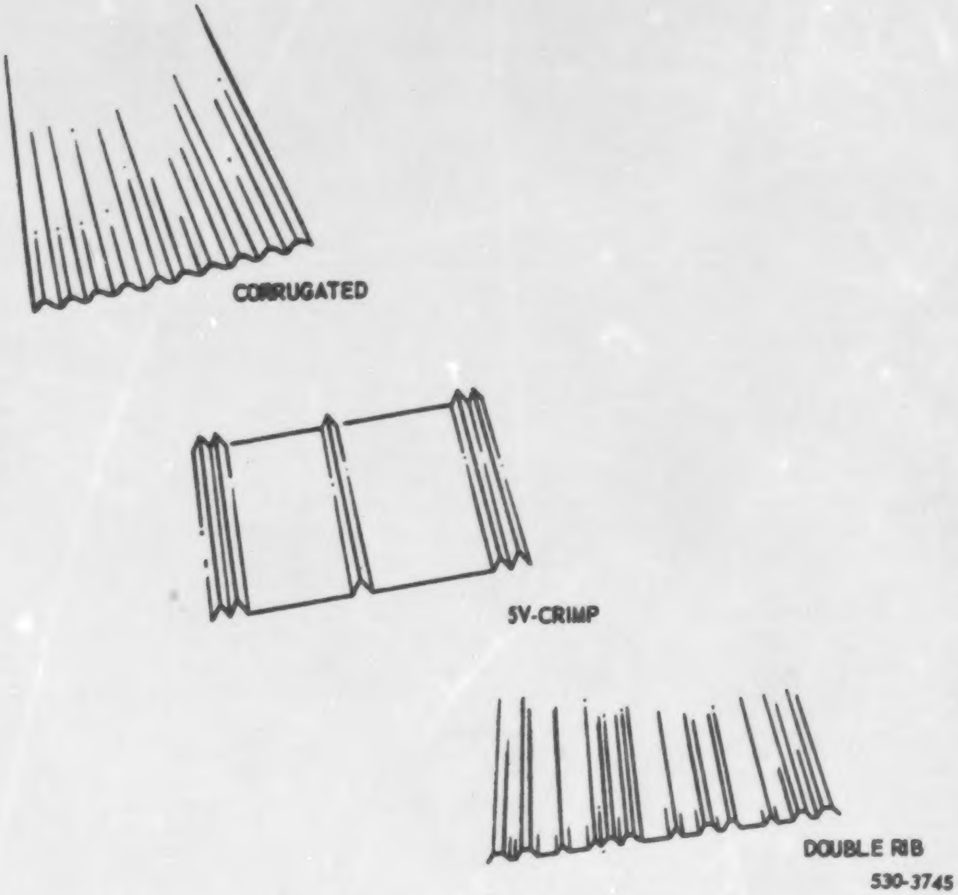

Figure 114. Shapes of metal roofing.

screws, or bolts made of aluminum, cadmium-plated steel, or stainless steel.

20-7. *Galvanized iron sheets.* The galvanized sheets used on roofs may be flat, corrugated, or 5 V-crimp. Galvanized sheet iron does not have as much resistance to corrosion as aluminum or copper, but it is very good for covering roofs. Two advantages that galvanized sheets have over aluminum and copper are lower cost and greater strength. Properly installed galvanized metal roofs will render satisfactory service and are often installed on sheds and warehouses. Fasten galvanized iron with nails, screws, or bolts made of cadmium-plated steel.

20-8. **Seams Used with Metal Roofing.** Seams used with metal roofing are similar to those used in other sheet metal fabrication; however, the way some of them are made and used will vary.

20-9. In figure 115, some of the parts of a roof are shown. This roof has a pitch which you are already familiar with. Where two gables or ridges join, a valley is formed. Seams running parallel to the roof slope (pitch) are called parallel seams. The seams running across the slope are called cross seams.

20-10. *Roofing standing seams.* Roofing standing seams are generally used with flat sheets on pitched roofs. These seams are not soldered and therefore should not be used with a roof having a slope of less than 3 inches to the foot. A roof slope of 4 inches or more (to the foot) is desirable. Standing seams allow for expansion and contraction if a $\frac{1}{16}$-inch space is allowed, as shown in step B of figure 116. The metal is fastened to the roof with cleats that are spaced 12 inches apart. The cleat is nailed to the roof, and the remaining part of the cleat is formed into the seam. In figure 116, you can see how this is done. In step A, the edge of one sheet has been bent up 90°. The cleat is nailed to the roof so that it is flush against the 90° flange of the sheet. After nailing the cleat to the roof, the remaining metal is bent over the nail heads. This prevents the heads from working through the top sheet that is to be installed next.

20-11. In step B of figure 116, the second sheet is installed. It also has a flange turned up 90°; however, it extends above the flange on the first sheet. This longer flange is bent over the shorter flange to form the standing seam. In step C, you can see how this 90° bend is started. In step D, the metal is bent to 180° to form the standing seam. In steps E and F, you can see that the standing seam is turned another 180° to complete the double seam.

20-12. *Roofing grooved (flat) seams.* Roofing grooved seams (flat seams) are adaptable for roofs that have very little pitch (less than 3-inch slope to the foot). This seam is normally used when installing 14" x 20" sheets. The sheets are fastened to the roof deck with cleats that are spaced 12 inches apart. The cleats are nailed to the roof deck and then formed into the grooved seam. In figure 117, you can see how the metal sheets are fastened to a roof with cleats. In figure 118, you can see how a cleat is formed into a grooved seam. Grooved seams are sealed with 50/50 solder. When a roof is installed with grooved seams, there must be expansion joints at intervals specified on the drawing.

20-13. *Roofing lap seams.* Roofing lap seams are used to install corrugated, 5 V-crimp, or rib sheets on a roof. The lap seams used in roofing are somewhat different than in other fabrication because the seams are lapped more. When installing corrugated, rib, or 5 V-crimp sheets, a definite number of sidelaps and endlaps must be maintained. Endlaps should not be less than 6 inches nor more than 8 inches.

20-14. Notice in view A of figure 119 how the sheets have crowns and valleys. In the following explanation of sidelaps, the terms "crown" and "valley" will be frequently used. A sidelap of 1½ corrugations means that one crown and one valley will be lapped. In view B, you can see a 1½ corrugation sidelap. In view C, there is a 2½ corrugation sidelap (notice that two crowns and one valley are lapped). In view D, there is a single sidelap on V-crimp roofing sheets, and one crown is covered. In view E, there is a 2-sidelap where both crowns and one valley are covered. Sidelaps on corrugated sheets should never be less than 2 corrugations. Sidelaps for V-crimp and rib sheets should not be less than 1 corrugation.

20-15. *Roofing batten seams.* Roofing batten seams, as shown in figure 120, are formed over battens made of wood. (A batten is a strip of wood nailed to the deck of a roof.) Batten seams run parallel to the slope of the roof and allow the metal to expand and contract. When cross seams are necessary to join the sheets (as shown in fig. 115), a grooved seam is used. These grooved cross seams are seldom soldered, but if they should be, allowance for expansion and contraction should be made at the eave or ridge.

20-16. Cleats are used to fasten the roofing to the batten somewhat like the cleats that are used for standing and grooved (flat) seams. In

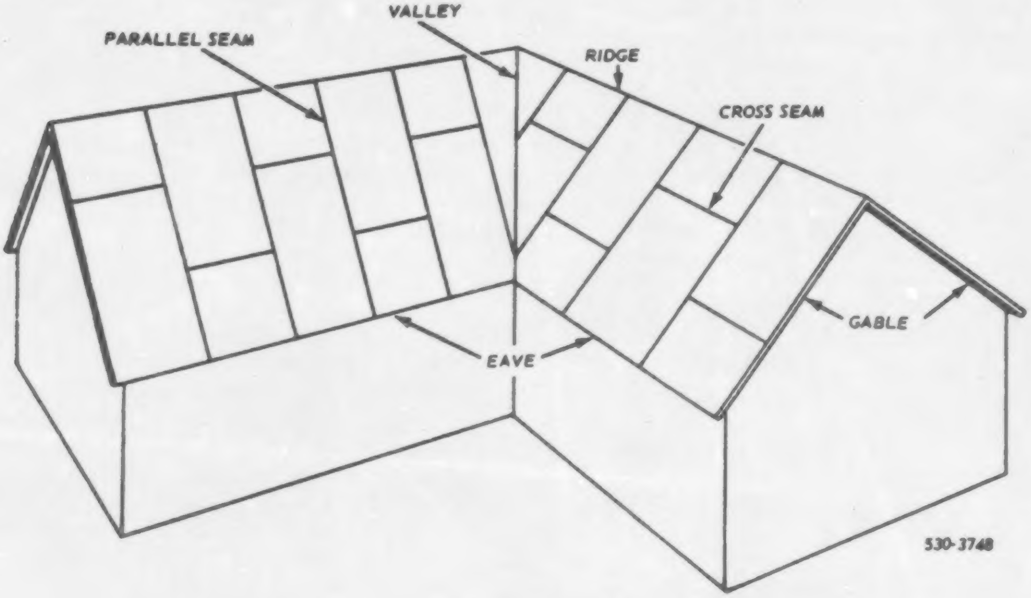

Figure 115. Parts of a roof

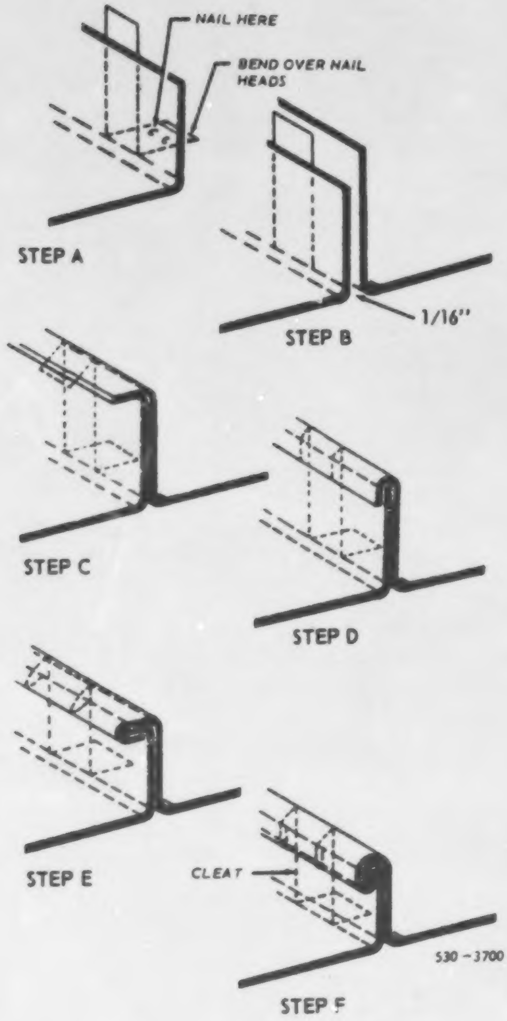

Figure 116. Roofing standing seam.

step A of figure 120, you can see the cleats nailed to a batten. In step B, the metal that has been formed 90° is placed along the right side of the batten. In step C, the metal is along both sides of the batten and the tabs which are formed over one edge of each channel. A cap piece is made into a channel and placed over the batten, as shown in step D. Both edges are turned 90° to make a single seam, as shown on the right side of step D. After this single seam is made, a double seam is made as shown in step E.

20-17. **Special Tools Used with Metal Roofing.** Special tools used to form roofing seams may be classified into three types: roofing seamers, roofing tongs, and roofing folders. The availability of these tools in your sheet metal shop depends upon the organization of your maintenance and repair branch. Some branches have a roofing crew which may work under the sheet metal shop and should have the necessary roofing tools.

20-18. *Roofing seamers.* Roofing seamers look somewhat like the hand seamer discussed in Volume 2. View A in figure 121 shows a conventional seamer, which is used to turn edges on metal for making roofing seams. It is available in different sizes for turning seams from ½ to 2 inches wide. Conventional seamers are not adjustable, and the correct size is required for making seams. The adjustable seamer shown in view B of figure 121 can be used to turn the edges for seams ¾ inch to 3 inches wide. The adjustment is made by loosening the wing nuts on each side of the blade.

20-19. The double seamer shown in view C of figure 121 is used to make double seams from standing seams as shown in figure 116. The bends are made with the folding jaws, and the edges are flattened with the squeezing jaws. These double seamers are available in two sizes: the common gage size that is used to make ¾-inch standing seams and the wide gage size that is used to make 1-inch standing seams. The double seamer folds the metal ¾ inch (or 1 inch) above the 90° flanges. This is different from the conventional and hand seamers which can bend the metal at the 90° flanges. Bending at the 90° flanges is necessary to convert roofing standing seams into grooved (flat) seams.

20-20. The hand double seamer, shown in view D of figure 121, acts as a backer when making a double seam on a standing seam. The seamer is placed against the opposite side of the standing seam, and a mallet is used to turn the edge. The double seamer in view C has a definite advantage over the one in view D because the seaming process can be done much faster with the dual-purpose tool.

20-21. *Roofing tongs.* The clamping tongs shown in figure 122 are used to clamp seams to hold them in place. The ring on one handle can be slipped over the other handle to keep the jaws tight. This allows the metal to be clamped while you continue working. The squeezing tongs, shown in figure 122, are used to tighten seams. For example, they can be used to tighten the pocket of a standing seam before making a double seam or grooved seam if a double seamer is not available.

20-22. *Roofing folders.* Roofing folders, such as those shown in figure 123, are used to turn edges for a grooved (flat) seam roof. These folders operate somewhat like a bar folder and have slots to prevent flattening of the edges that have already been turned. The common folder in view A is available in lengths of 14, 20, 28,

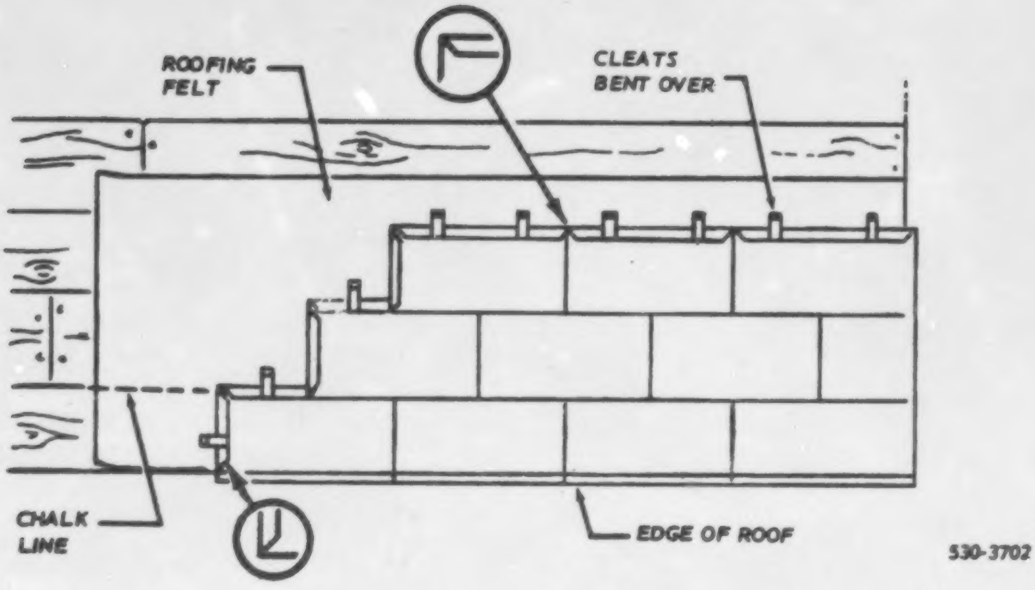
ROOFING FELT
CLEATS BENT OVER
CHALK LINE
EDGE OF ROOF
530-3702

Figure 117. Metal roofing installed with cleats.

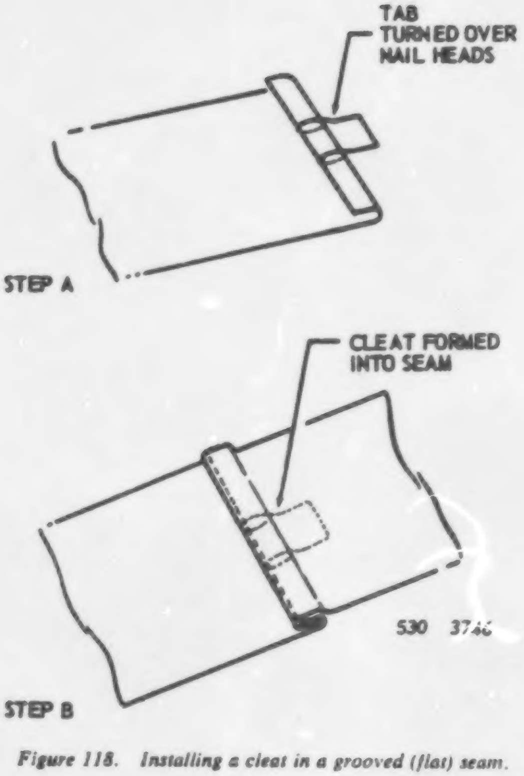
TAB TURNED OVER NAIL HEADS
STEP A
CLEAT FORMED INTO SEAM
530 3746
STEP B

Figure 118. Installing a cleat in a grooved (flat) seam.

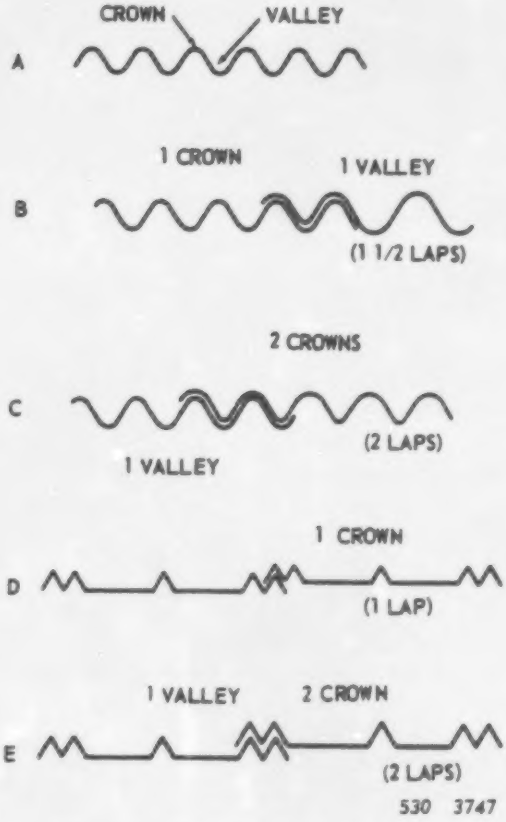
CROWN
VALLEY
A
1 CROWN
1 VALLEY
B
(1 1/2 LAPS)
2 CROWNS
C
1 VALLEY
(2 LAPS)
1 CROWN
D
(1 LAP)
1 VALLEY
2 CROWN
E
(2 LAPS)
530 3747

Figure 119. Sidelaps used with metal roofing.

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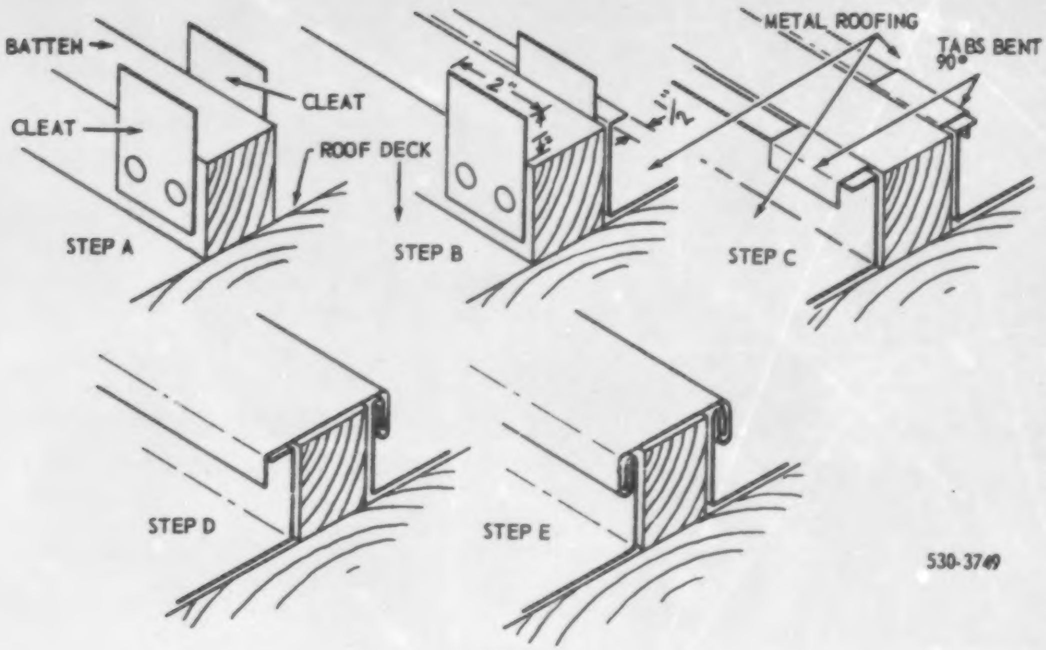


Figure 120. Making a batten seam.

and 30 inches and will turn an edge of $\frac{5}{16}$ inch. The adjustable folder in view B has a gage that can be set to form $\frac{3}{16}$- to ⅜-inch edges. Both of these folders have a bed, bending leaf, and operating handle. To form an edge, the metal is inserted into the folder and the handle pulled forward, as if using a bar folder.

20-23. **Installation of Metal Roofing.** Installation of metal roofing will involve the seams, tools, and fastening methods we have discussed in the preceding paragraphs. Now let's see how metal roofing is installed.

20-24. *Installing a roof with lap seams.* Lap seams are used when roofing sheets are made of corrugated, V-crimp, or ribbed metal. In figure 124 you can see how a corrugated roof is installed with lap seams. Endlaps are used so that the metal will lap over the top sheet in the direction of water flow toward the slope. Sidelaps are made so that the metal will lap over in the direction of the prevailing wind.

20-25. To lay corrugated roofing, such as is shown in figure 124, start with the sheet in the lower left-hand corner of the illustration. Sheet A is positioned and fastened to the purlin with number 14 x 1¾" self-tapping screws, except where the laps of sheets B, C, and E are joined. Sheet B is laid over sheet A so that a 1½ corrugation sidelap is made. It is fastened to the purlins just as sheet A was fastened. The sidelap is fastened with number 12 x ¾" self-tapping screws. Be very cautious when you are laying the sheets; stay on sheet A close to a purlin where the metal is rigid.

20-26. Next, sheet C is laid so that you have an endlap of 6 inches. Sheets A and C are fastened to the purlin with number 14 x 1¾" self-tapping screws, except where sheet E is to overlap. Sheet D is then laid and fastened to the purlins. Sheet E is laid over sheet C so that a 1½ corrugation sidelap is made and over sheet B so that a 6-inch endlap is made. This operation is continued until an expansion joint is reached. When V-crimp or ribbed sheet metal is used on a roof, the installation procedure is the same as for corrugated sheet metal.

20-27. An expansion joint may be made like the one shown in view A of figure 125. This is an end view of an expansion joint which will run the full length of the roof slope. To install the expansion joint, the flashing is fastened to the corrugated roofing with sheet metal screws which should be space 12 inches apart. The screws should have washers to prevent water from seeping around the heads. After the flashing is fastened to the roofing sheets, the cap is installed over the flange. Notice that the cap has a slight pitch so that water will run off.

20-28. The flashing in view B of figure 125 is for the gable edge of a roof. This is also an end view of the flashing. The gable flashing is seamed to the wall flashing and fastened to the roof with sheet metal screws. The flashing is installed so that it will overlap in the direction of the roof slope. Notice the drip edge on the gable flashing where it overlaps the corrugated roofing. This drip edge allows the water to run into the valley of the corrugated metal and off the roof.

20-29. The ridge caps, shown in view C of figure 125, are used to seal the ridge of a roof and are installed after the roof is laid. The ridge cap in view C–1 is shop made and extends over the ridge 7¼ inches. The cap shown in view C–2 is factory made and has a rolled edge on the top. The factory cap will usually extend over the ridge about 7¼ inches on each side. Both cap strips can be installed with sheet metal screws and a rubber closure strip. When the closure strip is used, the edge with the cutout for the corrugation should be set on the corrugated metal so that the cap stripe will rest on the flat edge, opposite to the cutout. The cutout of the closure strip should match the corrugation. In view D of figure 125, you can see a cap that is installed with a closure strip. The sheet metal screws or bolts pass through the ridge cap and closure strip and into the corrugated initial roof.

20-30. *Installing a roof with grooved (flat) seams.* Grooved seams, sometimes called *flat seams*, are normally used on roofs that have a low pitch (½ to 3 inches). The roof shown in figure 117 is installed with flat seams and cleats. When cutting and notching, make sure that a good notch is obtained; otherwise, a good solder joint will be hard to make. A good notch is shown in view A of figure 126. It will look like view B after the edges are turned. Notice that two edges are turned up and two are turned down. This allows the "down" edges to be hooked over the "up" edges, as shown in figure 117.

20-31. When laying a flat seam, the eave and gable strips are nailed, as shown in C and D of figure 126. The flashing for the eave is installed with cleats and a continuous strip, as shown in view C. The flashing should not be nailed to the roof deck. Notice that a ¾-inch pocket is turned over the strip. After the eave

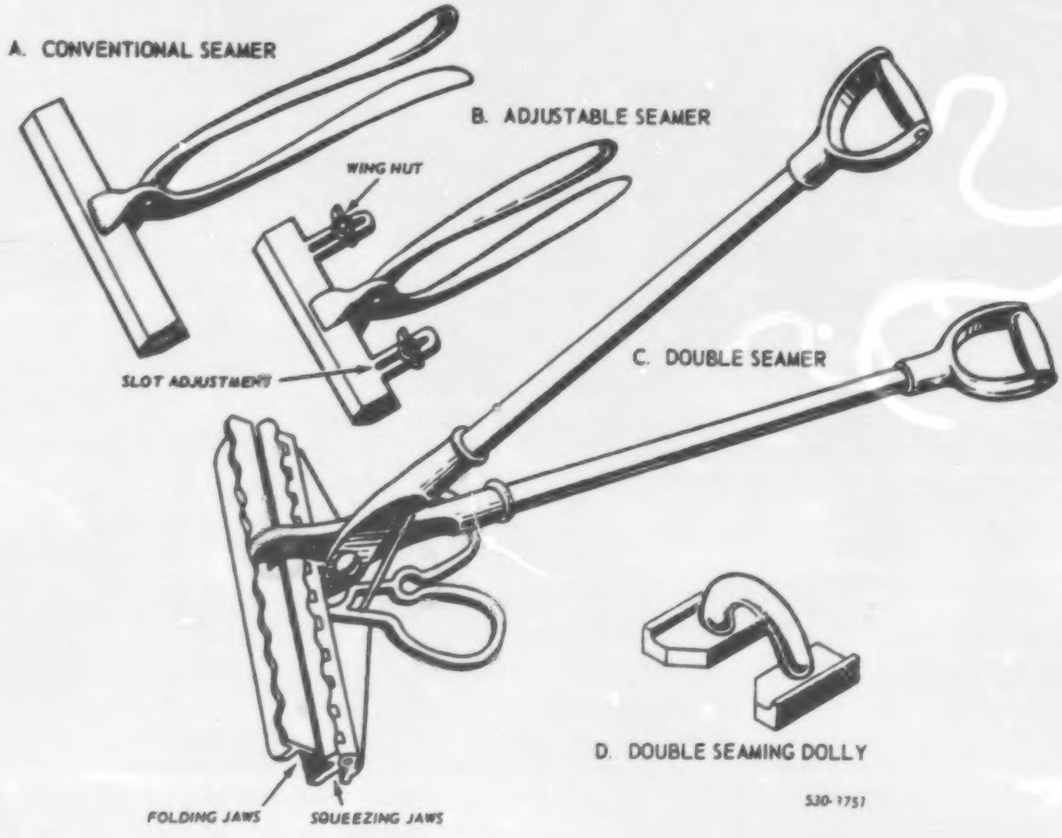


Figure 121. Roofing seamers.

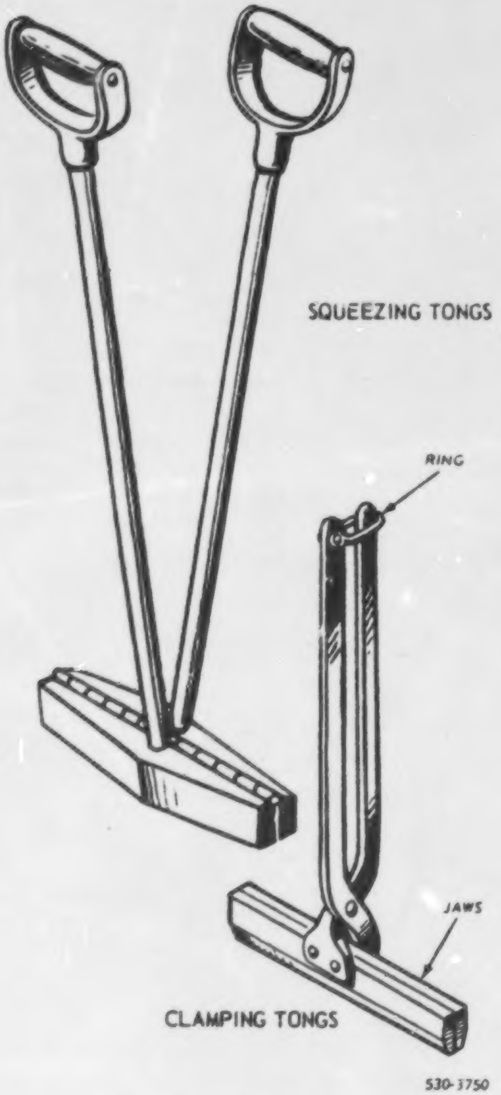


Figure 122. Roofing tongs.

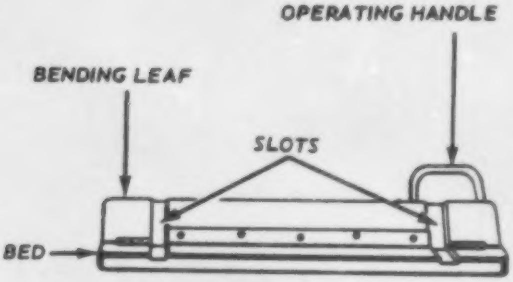
flashing is installed, the flat sheets with two edges turned down are inserted into the pockets of the flashing. In view D, the gable edge is shown. The sheet and grooved (flat) seam are lapped over the gable, and a ¾-inch pocket is turned. When covered this way, the roof deck eaves and gables are sealed from moisture.

20-32. When the flat sheets are installed on a roof, as shown in figure 117, make sure that the cleats are spaced correctly and that the seams are well grooved. Flatten them with a mallet and set the grooves with a hand groover. Cover the entire roof to within 7½ inches of the ridge, as shown in E of figure 126. This ridge cap is made in two halves: one half with the allowance for a standing seam pocket and the other half with a flange. The other edges of both halves will be turned down for a grooved (flat) seam. The ridge cap can be cut and formed in the shop with squaring shears and a cornice brake. The roof cap is fastened to the roof deck with cleats.

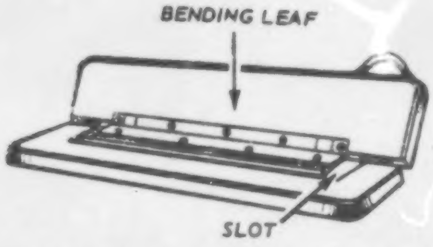
20-33. The grooved (flat) seam edges of the ridge cap halves are inserted in pockets of the roofing sheets, and the seams are flattened. The pocket for the standing seam on the ridge in figure 126 is turned and flattened with the double seamer, as shown in figure 116. However, a conventional seamer and a mallet must be used to fold the seam completely over, as shown in view E of figure 126.

20-34. All the seams on a grooved (flat) seam roof are soldered, usually with 50/50 bar solder. Equipment needed includes solder, flux, soldering coppers, and a firepot. The solder is carefully sweated into the seams to insure a well-sealed joint.

20-35. *Installing a roof with standing seams.* Procedures for installing a roof with standing seams are shown in figure 127. View A shows that the deck is covered with roofing felt, and some of the sheets are installed with double lock standing seams. The seams are made as shown in figure 116.



A. COMMON ROOFING FOLDER



B. ADJUSTABLE ROOFING FOLDER

530-3740

Figure 123. Roofing folders.

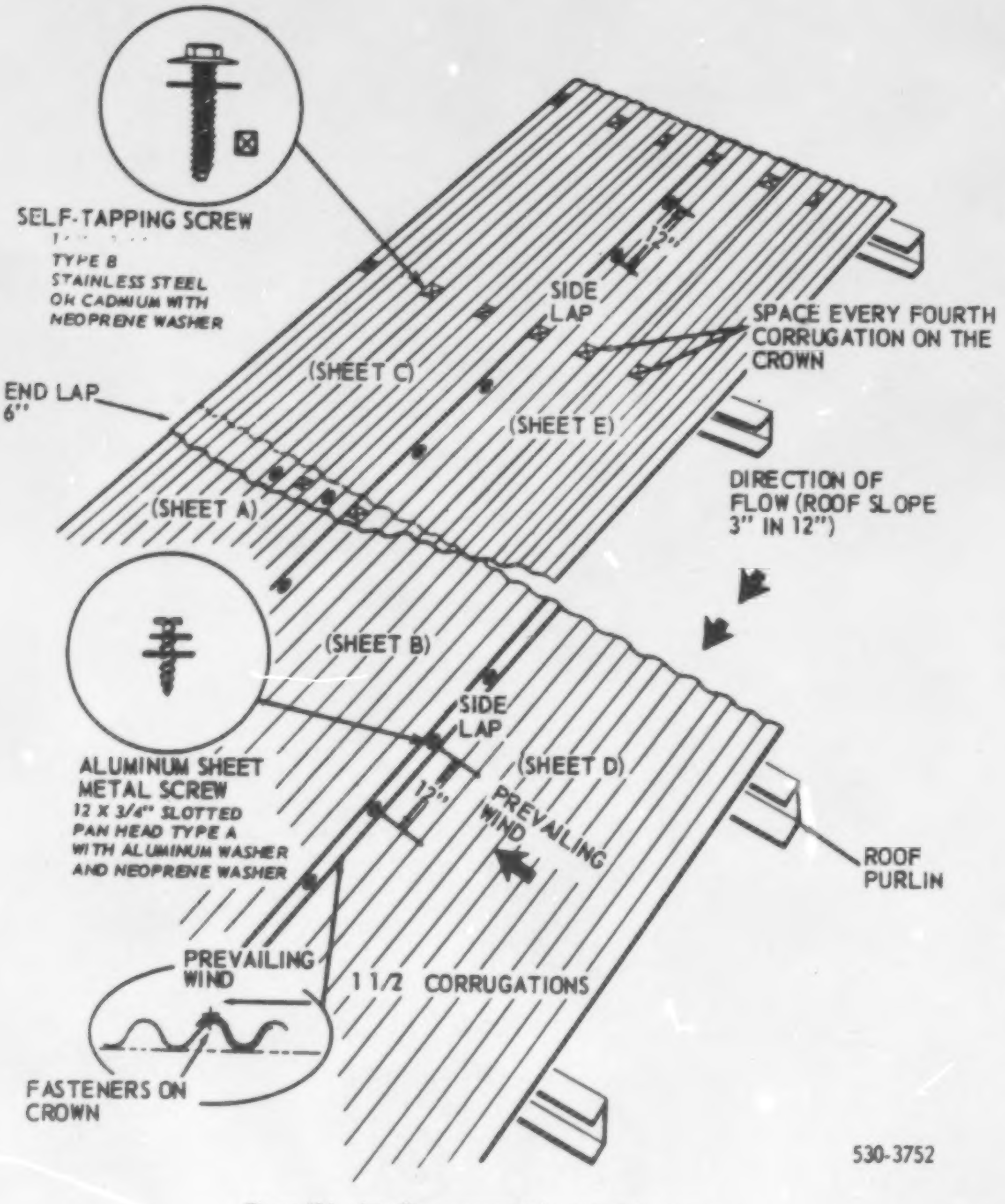
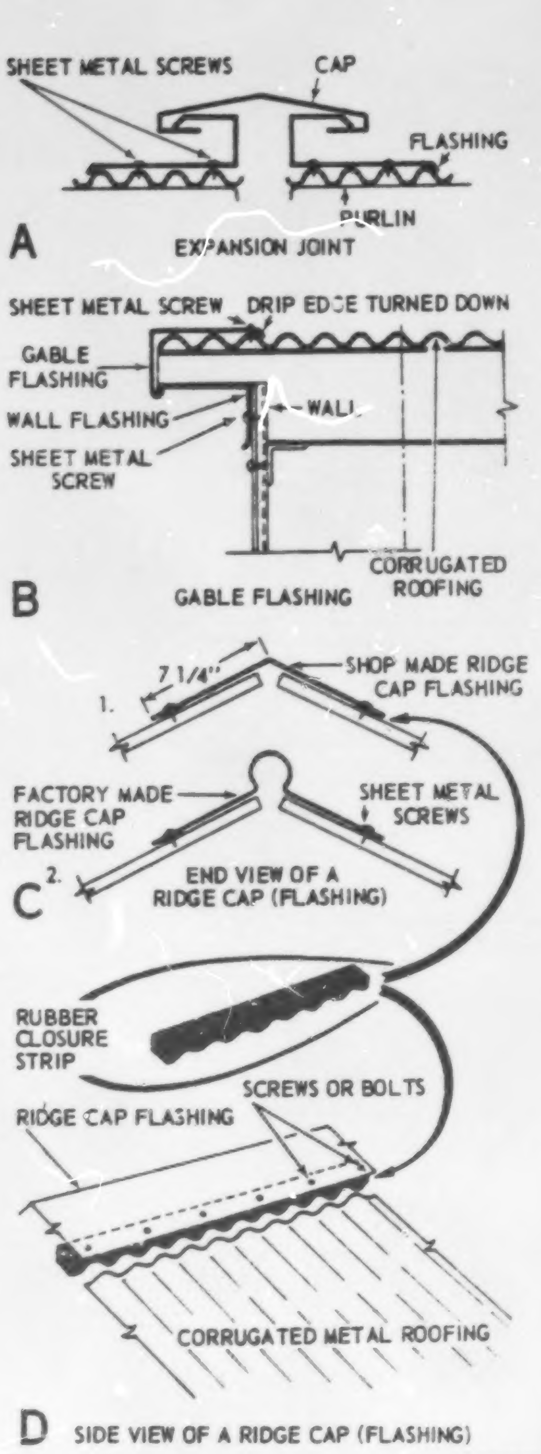

SELF-TAPPING SCREW
TYPE B
STAINLESS STEEL
OR CADMIUM WITH
NEOPRENE WASHER
12"
SIDE
LAP
SPACE EVERY FOURTH
CORRUGATION ON THE
CROWN
END LAP
6"
(SHEET C)
(SHEET E)
(SHEET A)
DIRECTION OF
FLOW (ROOF SLOPE
3" IN 12")
(SHEET B)
SIDE
LAP
ALUMINUM SHEET
METAL SCREW
12 X 3/4" SLOTTED
PAN HEAD TYPE A
WITH ALUMINUM WASHER
AND NEOPRENE WASHER
(SHEET D)
12"
PREVAILING
WIND
ROOF
PURLIN
PREVAILING
WIND
1 1/2 CORRUGATIONS
FASTENERS ON
CROWN
530-3752

Figure 124. Installing a corrugated roof with lap seams.

20-36. In view B of figure 127, you can see how the eave flashing is installed to prevent leaks. The continuous eave strip in this example is formed into a Z-shape and nailed to the roof deck; it extends over the eave ¾ inch. The metal roofing is placed on the deck so that a ¾-inch pocket can be formed over the ¾ inch of the eave strip that extends past the eave edge. The ends of the standing seams are turned 180° and flattened to prevent leaks.

20-37. Flashing for the gable edge is shown in view C of figure 127. A strip is nailed the entire length of the gable to the gable edge so that it will extend past the bottom of the gable edge


SHEET METAL SCREWS
CAP
FLASHING
PURLIN
A
EXPANSION JOINT
SHEET METAL SCREW
DRIP EDGE TURNED DOWN
GABLE FLASHING
WALL FLASHING
WALL
SHEET METAL SCREW
CORRUGATED ROOFING
B
GABLE FLASHING
7 1/4"
SHOP MADE RIDGE CAP FLASHING
1.
FACTORY MADE RIDGE CAP FLASHING
SHEET METAL SCREWS
C
2.
END VIEW OF A RIDGE CAP (FLASHING)
RUBBER CLOSURE STRIP
SCREWS OR BOLTS
RIDGE CAP FLASHING
CORRUGATED METAL ROOFING
D
SIDE VIEW OF A RIDGE CAP (FLASHING)

530-3753

Figure 125. Installing roofing joints and sealers.

¾ inch. A piece of flashing needs to be wide enough to form a ¾-inch pocket, a 1-inch standing seam, and a ½-inch double seam plus the roof deck thickness. The ¾-inch pocket is formed with a cornice brake, and the double seam is formed with the double seamer as the flashing is installed.

20-38. The ridge is capped as shown in view D of figure 127. This is done by nailing cleats to the roof deck and forming them into the standing double seam. When the standing seam in view E joins the standing seam on the ridge, the seam on the slope is flattened and formed into the ridge seam, as shown in view E.

20-39. The cross seams are joined with ½-inch grooved seams, as shown in view F of figure 127. The cross seams are sealed with solder. The cross seam is also sealed where it is formed into the double fold of the standing seam.

20-40. *Installing a roof with batten seams.* Installing a roof with batten seams is done by making the seams over the batten strips which are nailed to the roof deck. To refresh your memory of a batten seam, refer to figure 120, which shows how a batten seam is made. Figure 128 shows how the batten seams are sealed at the ridge, eave, gable, and cross seams. In view A, the roofing is formed to and up the side of the ridge batten. In view B, a ½-inch edge is turned so that the cap can be turned over the edge to form a pocket. After the pocket is turned on each side of the ridge cap, the pocket is flattened.

20-41. The gable flashing, shown in view C, is made by turning a pocket on the batten that can be fastened to the strip which is nailed to the edge of the roof deck. The gable flashing extends up from the edge of the roof, turns 90° across the top of the batten, and is seamed into the roofing that extends up the other side of the batten.

20-42. The eave end of the batten seam is sealed, as shown in views D, E, F, and G. First, an end cap is made with ½-inch edges turned up 90°, as shown in view D. Second, the roofing is extended 1 inch past the eave, and a ½-inch pocket is made as shown in view E. Third, a cap strip is made and extended 1 inch past the eave, a ½-inch pocket is formed, and the seams are turned, as shown in view F. Fourth, the cap strip is flattened over the end of the batten as shown in view G; this seals the eave end of the batten seam.

20-43. **Repair of Metal Roofing.** Repair of metal roofing is seldom necessary if the roofing was properly installed; however, in some cases a seam may crack or the metal may break, thus necessitating repair.

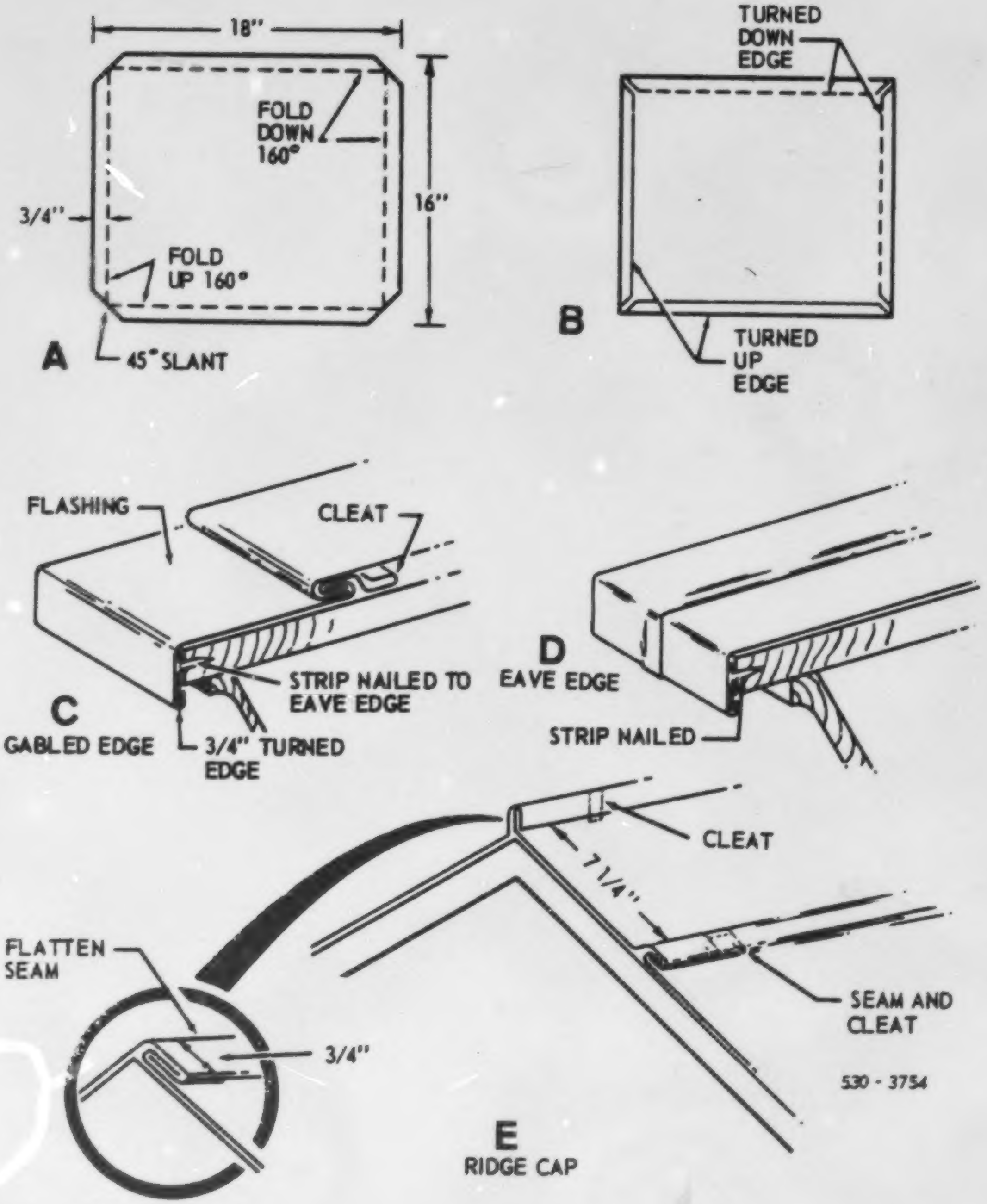

18"
16"
FOLD DOWN 160°
3/4"
FOLD UP 160°
A
45° SLANT
TURNED DOWN EDGE
B
TURNED UP EDGE
FLASHING
CLEAT
STRIP NAILED TO EAVE EDGE
C
GABLED EDGE
3/4" TURNED EDGE
D
EAVE EDGE
STRIP NAILED
CLEAT
7 1/4"
FLATTEN SEAM
3/4"
SEAM AND CLEAT
530 - 3754
E
RIDGE CAP

Figure 126. Grooved (flat) seams used with metal roofing.

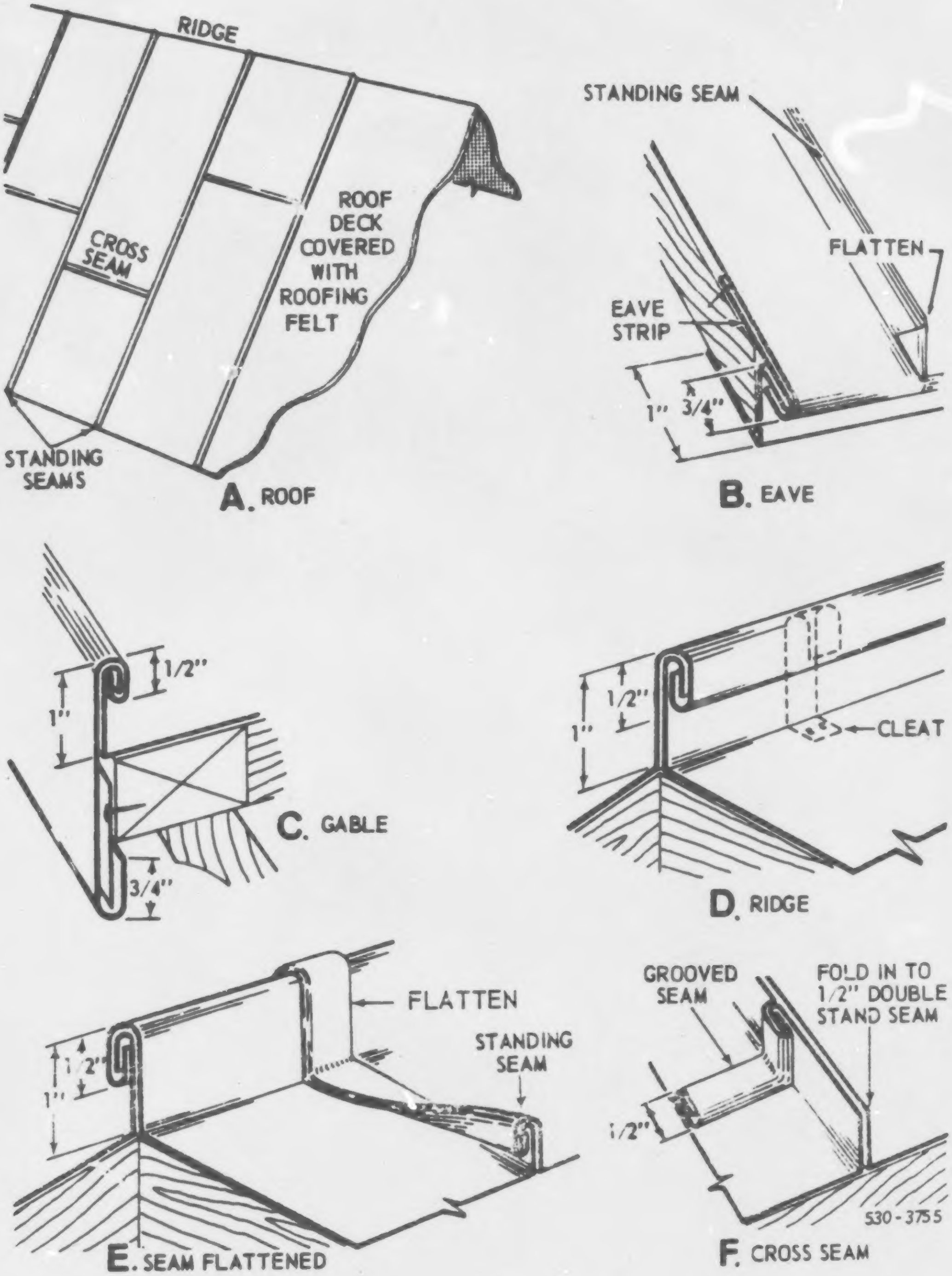

RIDGE
CROSS SEAM
ROOF DECK COVERED WITH ROOFING FELT
STANDING SEAMS
A. ROOF
STANDING SEAM
FLATTEN
EAVE STRIP
1"
3/4"
B. EAVE
1/2"
1"
3/4"
C. GABLE
1/2"
1"
CLEAT
D. RIDGE
FLATTEN
STANDING SEAM
1/2"
1"
E. SEAM FLATTENED
GROOVED SEAM
FOLD IN TO 1/2" DOUBLE STAND SEAM
1/2"
530-3755
F. CROSS SEAM

Figure 127. Standing seams used with metal roofing.

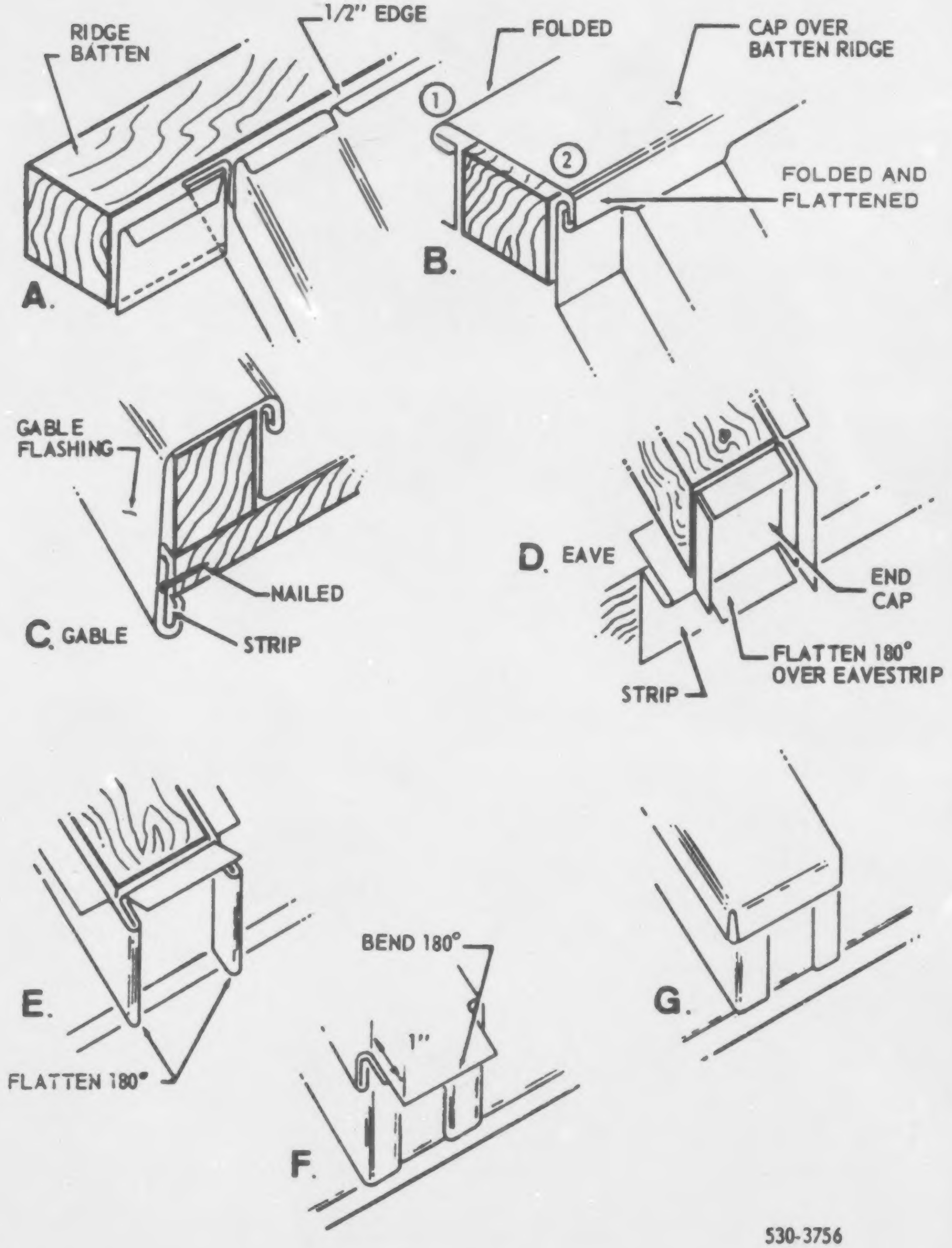

RIDGE BATTEN
1/2" EDGE
A.
FOLDED
CAP OVER BATTEN RIDGE
①
②
FOLDED AND FLATTENED
B.
GABLE FLASHING
NAILED
C. GABLE
STRIP
D. EAVE
END CAP
FLATTEN 180° OVER EAVESTRIP
STRIP
E.
FLATTEN 180°
BEND 180°
1"
F.
G.
530-3756

Figure 128. Batten seams used with metal roofing.

20-44. *Copper roofing*. Copper roofing is usually installed with grooved (flat) seams, batten seams, or standing seams. Therefore, the most common cause of trouble is inadequate expansion joints. If cracks occur, an expansion joint should be installed. Small holes and breaks in copper can be repaired by soldering the hole or break. The surface around the break should be cleaned with a wire brush or emery cloth, flux applied, and the spot soldered. Large breaks can be repaired by soldering a patch over the break.

20-45. *Galvanized iron roofing*. Galvanized iron roofing will not require very much repair if it is installed and maintained properly. A galvanized roof should be painted after it is allowed to set for a few months. The surface is ready for paint when it has turned to a dull gray color. The metal should be painted regularly to prolong the life of the metal. Repairs to a galvanized iron roof are usually due to small breaks and holes which can be repaired by soldering. A sheet with a large break is removed and replaced.

20-46. *Aluminum roofing*. Aluminum roofing is repaired somewhat like galvanized iron roofs. Usually, the sheet which is damaged will need replacing; however, small holes and cracks can be repaired with a patch. If a patch is made, use the same of type of metal that was used on the original roof. Since roofs with steel purlins do not normally have decking and the roofing can be reached from both sides, a patch can be riveted to the metal.

21. Flashing

21-1. Flashing is used with metal roofing, shingle roofing, tar and gravel roofing, and built-up asphalt roofing to weatherproof the joints and edges. Although we have already mentioned flashing in the discussions about metal roofing, you should know more about the various types of flashing and how they are fabricated, installed and repaired. You may also recall that flashing was used with stacks and ventilators.

21-2. **Types of Flashing.** Flashing consists of many types, such as valley, fascia, corner, gable, and ridge. When made of metal, flashing may be copper, aluminum, lead, or galvanized iron.

21-3. *Valley flashing*. Valley flashing, such as shown in figure 129, is used where two sloping roofs join. Valley flashing may be fastened to roof decks, sides of buildings, edges of gables and eaves, and ridges with cleats, nails, screws, or nuts and bolts. In some cases, flashing may be riveted; however, the type of fastening device is usually specified on the drawing. The kind of metal used on the roof will determine the kind of material for the flashing and fasteners. Remember that dissimilar metals are not to be joined. If copper flashing is held by cleats, copper or bronze nails should be used to fasten the cleats to the roof deck. The upper end should lap under the ridge cap, and the lower end should lap over the eave.

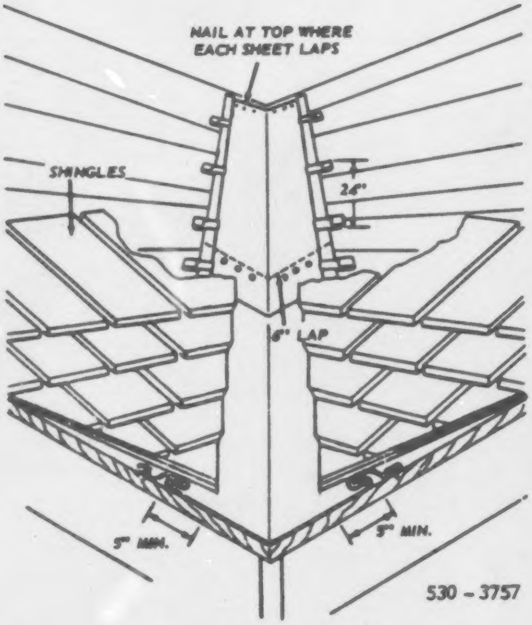
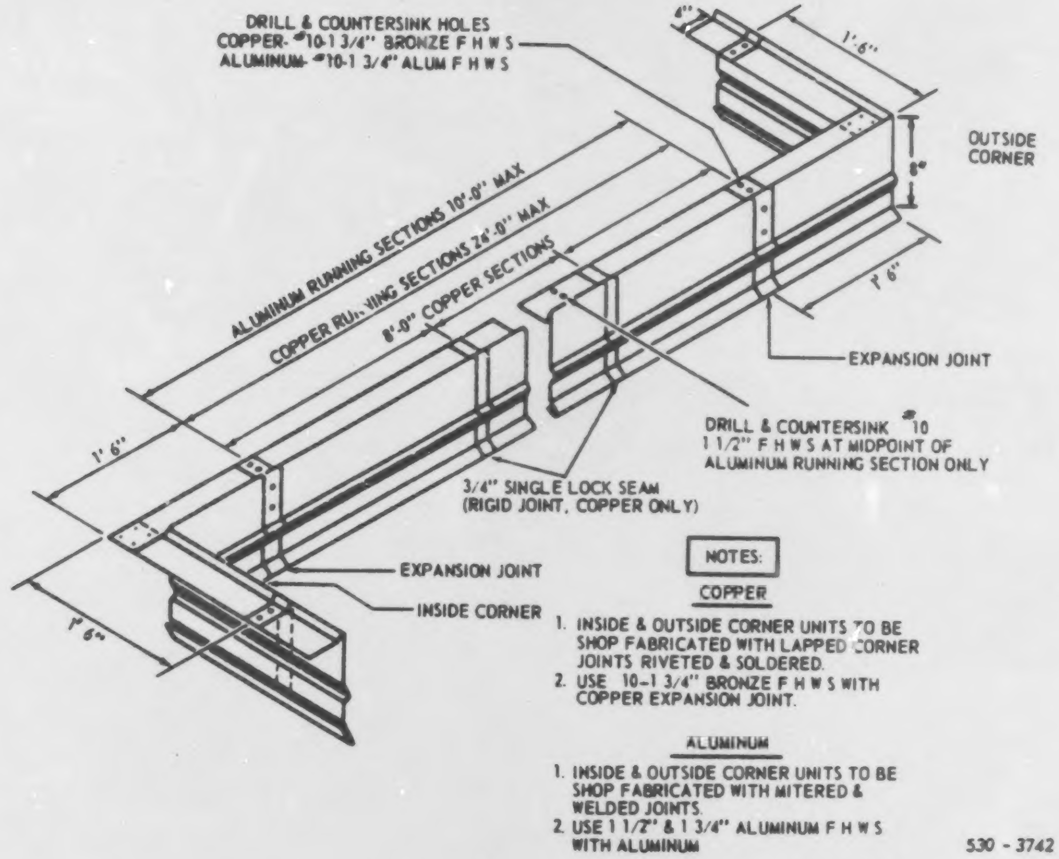


Figure 129. Valley flashing.

21-4. *Fascia and gravel guard flashing*. The fascia and gravel guard flashing, shown in figure 130, should not be over 8 feet long, and it should be wide enough to extend under the roofing material 4 inches. The fascia should have a ½-inch V-crimp, as shown in figure 131 if the width is over 5 inches. The bottom of the metal fascia flashing is secured with a continuous strip that is nailed to the bottom of the fascia board. The metal strip has nails spaced on 6-inch centers. The bottom edge of the fascia flashing has a 1-inch pocket formed over the strip and bent 45° to form a drip edge. Expansion joints such as those shown in figure 132 should be used at intervals specified on the drawings. These expansion joints should allow for ¼ inch of expansion and contraction. The expansion joint should extend over the roof 4 inches and cover the full width of the fascia flashing. When the fascia flashing is spliced, the butt joint should be concealed with a cap strip. The cap strip should have the same shape as the fascia and should lap the fascia 2 inches each direction from the splice.

21-5. *Gable flashing*. Gable flashing is used to seal the edge of a roof at the gable. In view B of figure 125, the flashing is formed over the edge


DRILL & COUNTERSINK HOLES
COPPER- #10-1 3/4" BRONZE F H W S
ALUMINUM- #10-1 3/4" ALUM F H W S
4"
1'-6"
OUTSIDE CORNER
8"
1'-6"
ALUMINUM RUNNING SECTIONS 10'-0" MAX
COPPER RUNNING SECTIONS 24'-0" MAX
8'-0" COPPER SECTIONS
EXPANSION JOINT
DRILL & COUNTERSINK #10
1 1/2" F H W S AT MIDPOINT OF
ALUMINUM RUNNING SECTION ONLY
1'-6"
3/4" SINGLE LOCK SEAM
(RIGID JOINT, COPPER ONLY)
EXPANSION JOINT
INSIDE CORNER
1'-6"

NOTES:

COPPER

1. INSIDE & OUTSIDE CORNER UNITS TO BE SHOP FABRICATED WITH LAPPED CORNER JOINTS RIVETED & SOLDERED.
2. USE 10-1 3/4" BRONZE F H W S WITH COPPER EXPANSION JOINT.

ALUMINUM

1. INSIDE & OUTSIDE CORNER UNITS TO BE SHOP FABRICATED WITH MITERED & WELDED JOINTS.
2. USE 1 1/2" & 1 3/4" ALUMINUM F H W S WITH ALUMINUM

530 - 3742

Figure 130. Gravel guard and fascia.

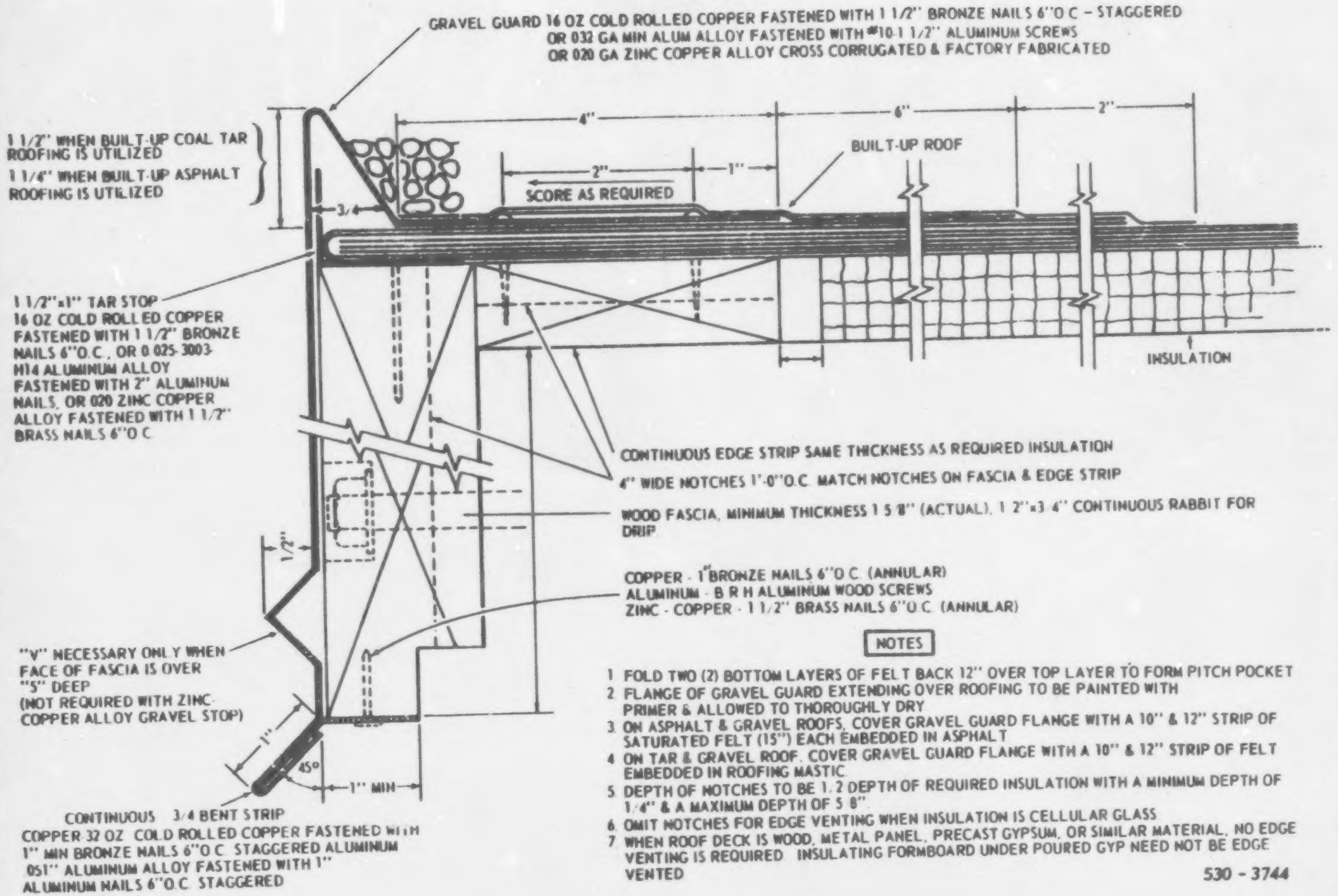
of the gable. Notice how a drip edge is turned on the top part of the flashing so that water will be discharged into the valley of the corrugated roof. The bottom edge is formed into a pocket to join the wall flashing. This will completely seal the gable edge from moisture. In view D of figure 126, you can see how the gable flashing is fastened to the roof with a metal strip. The flashing is formed over the strip so that the flashing is fastened at the bottom.

21-6. *Eave flashing*. Eave flashing such as that shown in view C of figure 126 is used to seal the eaves of roofs. Gable and eave flashings are used on most roofs, including asphalt shingle, built-up asphalt, tar and gravel, or metal. The working drawings should specify how the eave flashing is to be made.

21-7. *Ridge flashing*. An example of ridge flashing for roofs is shown in views C and D of figure 125. The metal ridge cap (flashing) is used on many types of roofs. In the previous sections about roofing, we discussed how this flashing is fastened on metal roofs. On roofs such as asphalt shingle, the flashing can be fastened with nails, and the ends should lap at least 4 inches.

21-8. *Base flashing*. Base flashing such as that used around the ventilator shown in figure 47 should extend over the roof deck at least 4 inches. Notice that the flashing is in one piece and is bent so that it extends above the roof deck. Base flashing should extend up a wall or a frame at least 8 inches and should overlap 3 inches where the pieces join.

21-9. **Fabrication of Flashing.** Fabrication of flashing consists of laying out patterns, cutting, notching, and forming. In the following example of flashing fabrication, 16-ounce copper will be used. Several sections of the fascia and gravel guard flashing shown in figures 130, 131, and 132 will be fabricated. Figure 133 shows the patterns: view A is the pattern for the straight sections and view B is for the corners. The measurements and bending instructions will make one 8-foot straight piece and an inside or outside corner. The overall width of the

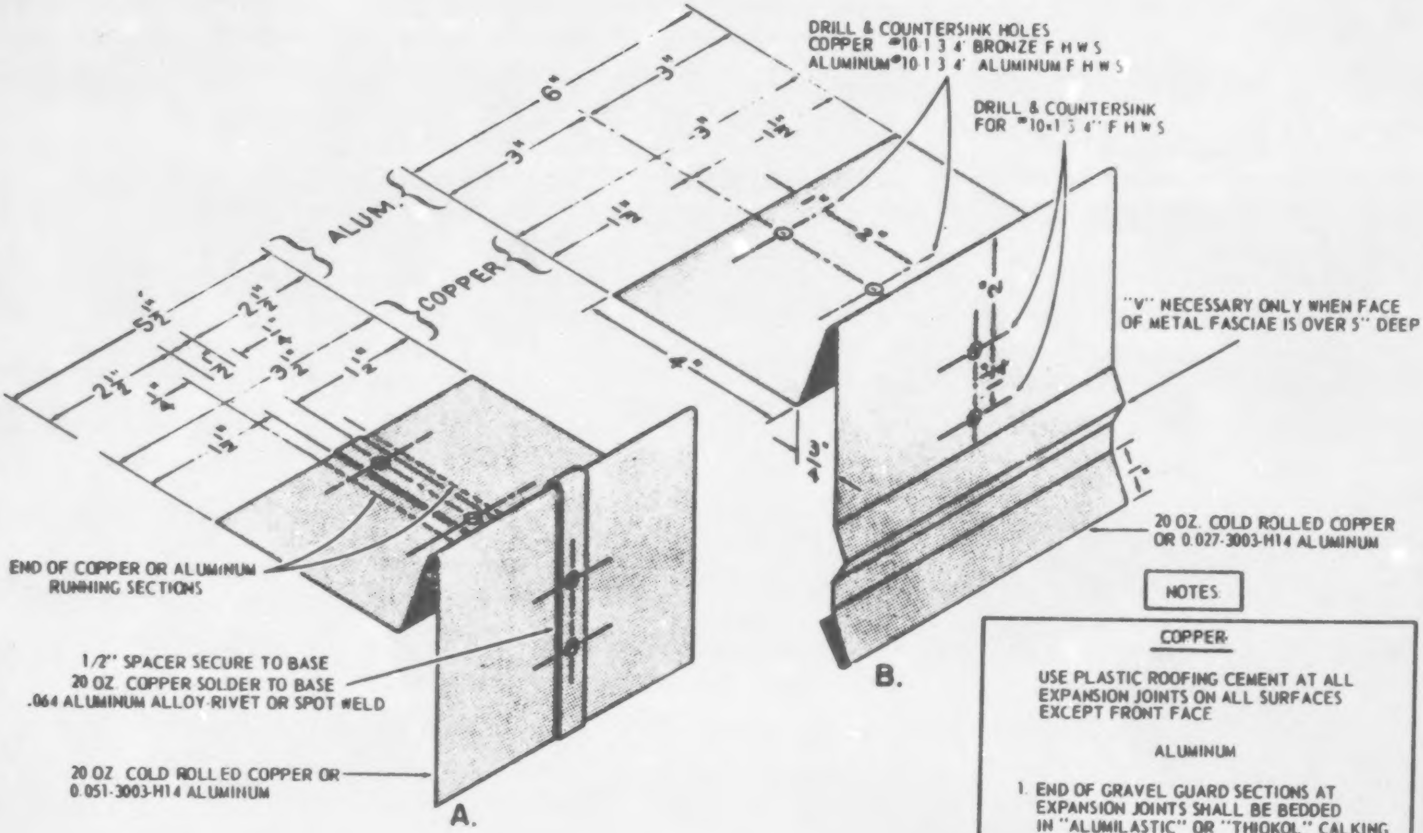

GRAVEL GUARD 16 OZ COLD ROLLED COPPER FASTENED WITH 1 1/2" BRONZE NAILS 6"O C – STAGGERED
OR 032 GA MIN ALUM ALLOY FASTENED WITH #10-1 1/2" ALUMINUM SCREWS
OR 020 GA ZINC COPPER ALLOY CROSS CORRUGATED & FACTORY FABRICATED
1 1/2" WHEN BUILT-UP COAL TAR ROOFING IS UTILIZED
1 1/4" WHEN BUILT-UP ASPHALT ROOFING IS UTILIZED
4"
6"
2"
2"
1"
SCORE AS REQUIRED
BUILT-UP ROOF
3/4
INSULATION
1 1/2"x1" TAR STOP 16 OZ COLD ROLLED COPPER FASTENED WITH 1 1/2" BRONZE NAILS 6"O.C., OR 0 025-3003-H14 ALUMINUM ALLOY FASTENED WITH 2" ALUMINUM NAILS, OR 020 ZINC COPPER ALLOY FASTENED WITH 1 1/2" BRASS NAILS 6"O C
CONTINUOUS EDGE STRIP SAME THICKNESS AS REQUIRED INSULATION
4" WIDE NOTCHES 1'-0"O.C. MATCH NOTCHES ON FASCIA & EDGE STRIP
WOOD FASCIA, MINIMUM THICKNESS 1 5/8" (ACTUAL), 1/2"x3/4" CONTINUOUS RABBIT FOR DRIP
COPPER - 1" BRONZE NAILS 6"O C (ANNULAR)
ALUMINUM - B R H ALUMINUM WOOD SCREWS
ZINC - COPPER - 1 1/2" BRASS NAILS 6"O C (ANNULAR)
1/2"
"V" NECESSARY ONLY WHEN FACE OF FASCIA IS OVER "5" DEEP (NOT REQUIRED WITH ZINC-COPPER ALLOY GRAVEL STOP)
1"
45°
1" MIN
CONTINUOUS 3/4 BENT STRIP
COPPER 32 OZ COLD ROLLED COPPER FASTENED WITH 1" MIN BRONZE NAILS 6"O C STAGGERED ALUMINUM .051" ALUMINUM ALLOY FASTENED WITH 1" ALUMINUM NAILS 6"O.C STAGGERED
530 - 3744

NOTES

1 FOLD TWO (2) BOTTOM LAYERS OF FELT BACK 12" OVER TOP LAYER TO FORM PITCH POCKET
2 FLANGE OF GRAVEL GUARD EXTENDING OVER ROOFING TO BE PAINTED WITH PRIMER & ALLOWED TO THOROUGHLY DRY
3 ON ASPHALT & GRAVEL ROOFS, COVER GRAVEL GUARD FLANGE WITH A 10" & 12" STRIP OF SATURATED FELT (15") EACH EMBEDDED IN ASPHALT
4 ON TAR & GRAVEL ROOF. COVER GRAVEL GUARD FLANGE WITH A 10" & 12" STRIP OF FELT EMBEDDED IN ROOFING MASTIC
5 DEPTH OF NOTCHES TO BE 1/2 DEPTH OF REQUIRED INSULATION WITH A MINIMUM DEPTH OF 1/4" & A MAXIMUM DEPTH OF 5/8"
6 OMIT NOTCHES FOR EDGE VENTING WHEN INSULATION IS CELLULAR GLASS
7 WHEN ROOF DECK IS WOOD, METAL PANEL, PRECAST GYPSUM, OR SIMILAR MATERIAL, NO EDGE VENTING IS REQUIRED INSULATING FORMBOARD UNDER POURED GYP NEED NOT BE EDGE VENTED

Figure 131. Fabrication detail for fascia and gravel guard flashing.

36


DRILL & COUNTERSINK HOLES
COPPER #10 1 3 4' BRONZE F H W S
ALUMINUM #10 1 3 4' ALUMINUM F H W S
DRILL & COUNTERSINK
FOR #10×1 3 4'' F H W S
6"
3"
3"
3"
1½"
2"
ALUM.
COPPER
5½"
2½"
2½"
1¼"
½"
3½"
1½"
¼"
1½"
4"
2"
¾"
1"
¾"
"V" NECESSARY ONLY WHEN FACE
OF METAL FASCIAE IS OVER 5" DEEP
20 OZ. COLD ROLLED COPPER
OR 0.027-3003-H14 ALUMINUM
END OF COPPER OR ALUMINUM
RUNNING SECTIONS
1/2" SPACER SECURE TO BASE
20 OZ. COPPER SOLDER TO BASE
.064 ALUMINUM ALLOY-RIVET OR SPOT WELD
20 OZ. COLD ROLLED COPPER OR
0.051-3003-H14 ALUMINUM
A.
B.

NOTES

COPPER

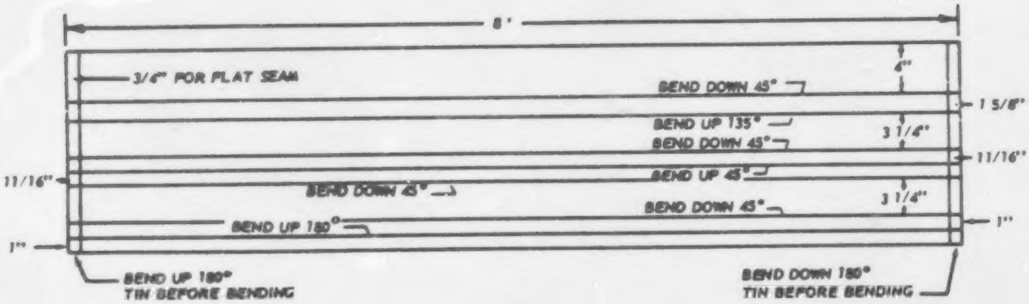
USE PLASTIC ROOFING CEMENT AT ALL EXPANSION JOINTS ON ALL SURFACES EXCEPT FRONT FACE

ALUMINUM

1. END OF GRAVEL GUARD SECTIONS AT EXPANSION JOINTS SHALL BE BEDDED IN "ALUMILASTIC" OR "THIOKOL" CALKING MATERIAL, APPLIED TO ALL SURFACES EXCEPT TO FRONT FACE.
2. SHOP SCRIBE RUNNING SECTIONS 2" FROM EACH END FOR GAUGING EXPANSION SPACE AT EXPANSION JOINTS
3. REINFORCE FELT STRIPPING AT EXPANSION JOINTS WITH AN 8"×12" FABRIC WITH FLAT TUCK OVER EACH EXPANSION JOINT

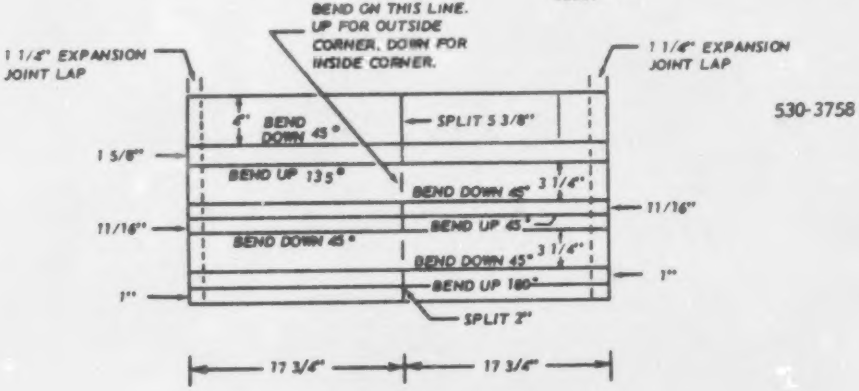
530 3743

Figure 132. Fabrication detail for an expansion joint.


8'
3/4" FOR FLAT SEAM
BEND DOWN 45°
4"
1 5/8"
BEND UP 135°
BEND DOWN 45°
3 1/4"
11/16"
11/16"
BEND UP 45°
BEND DOWN 45°
BEND DOWN 45°
3 1/4"
BEND UP 180°
1"
1"
BEND UP 180°
TIN BEFORE BENDING
BEND DOWN 180°
TIN BEFORE BENDING

A PATTERN FOR STRAIGHT PIECES

NOTE
THE 180° BEND IS NOT NEEDED ON ENDS THAT CONNECT TO THE EXPANSION JOINT


BEND ON THIS LINE. UP FOR OUTSIDE CORNER, DOWN FOR INSIDE CORNER.
1 1/4" EXPANSION JOINT LAP
1 1/4" EXPANSION JOINT LAP
530-3758
4"
BEND DOWN 45°
SPLIT 5 3/8"
1 5/8"
BEND UP 135°
BEND DOWN 45°
3 1/4"
11/16"
11/16"
BEND UP 45°
BEND DOWN 45°
BEND DOWN 45°
3 1/4"
BEND UP 180°
1"
1"
SPLIT 2"
17 3/4"
17 3/4"

B PATTERN FOR CORNER PIECES

Figure 133. Patterns for fascia and gravel guard flashing.

stretchout for pattern A is 15½ inches—2 inches for the pocket at the bottom, 3¼ inches to the bottom of the V, $^{11}/_{16}$ inch for each half of the V, 3¼ inches to the top of the gravel guard, 1⅝ inches for the slope of the gravel guard, and 4 inches to extend on the roof deck. Three 8-foot straight joints make up one 24-foot straight section. The center joint (view A of fig. 133) has grooved seams on each end. The other two straight joints have grooved seams at only one end.

21-10. The pattern for the corners shown in view B of figure 133 has the same stretchout dimensions as pattern A but is shorter in length, straight on both ends, and will be bent in the center. Two slits are made so that the pattern can be bent 90° for the corner. This pattern is bent up for the outside corners and down for the inside corners. The 1¼-inch allowance at each end is for the expansion joints.

21-11. *Cutting and slitting.* Cutting and slitting can be done with the squaring shears and straight cut snips. The back gage on the shears can be set for the 15½-inch stretchout and the desired number of pieces of metal cut. Notching is not required for either pattern; however, the corner pattern is slit as shown in figure 133. Cutting the 1½" x 1" tar stops from 16-ounce copper can be done on the squaring shears. Pieces of flat metal 8 feet long and 2½ inches wide are needed. The bottom strip of 32-ounce copper is cut 8 feet long and 1¾ inches wide.

21-12. *Forming.* Forming the patterns shown in figure 133 is done with the cornice brake. To form pattern A, first make the 180° bends on each end for the grooved seam pockets. After these bends have been made, make two small strips of metal about 1 inch wide and 16 inches long and insert them in the ¾-inch pockets. This will keep the pockets from being flattened when the other bends are made.

21-13. The next forming step is to bend the pattern lengthwise. Starting with the 1-inch pocket, make the 180° bend, then turn the metal over and make the 45° bend. Next, make the first 45° bend of the V-stiffener, turn the metal over and make a 45° bend, then turn the metal back over and make the other 45° bend of the V. Now, turn the metal back over and make the 135° bend. The last step is to turn the metal over again and make a 45° bend. This completes the forming of the long piece. Remove the strips from the pocket on each end of the metal.

21-14. Pattern B in figure 133 is formed the same as pattern A except that the metal is bent in the center. To make this bend (up or down), use the edge of a table and make the 90° bend by hand. When assembled, the outside corner pieces will have an overlapping of the roof deck and gravel guard allowances. This will form a square corner which is to be riveted and soldered. The inside corner pieces will require that a clip be made to fill the gap; it will be riveted and soldered.

21-15. Forming of the 2½-inch tar stop pieces is done on the cornice brake by making a 90° bend. The 1¾-inch strip for the bottom is formed on the cornice brake by making a 45° bend along a ¾-inch line. Nail holes in the bottom strip should have holes punched 6 inches on center so that the nails can be driven through the copper into the bottom edge of the wood fascia.

21-16. **Fabrication of an Expansion Joint.** To fabricate piece A of the expansion joint shown in figure 132, cut two pieces of 20-ounce copper ½" x 13⅝" and 5½" x 13⅝". To fabricate piece B, cut a piece of 20-ounce copper 6" x 15½". Form the pieces on the cornice brake to look like the pieces shown in figure 132. After forming, solder the ½-inch piece to the 5½-inch piece to make piece A. Drill and countersink the holes in piece B, as shown in the illustration. Use piece B as a template to mark the hole locations on piece A.

21-17. **Installation of Flashing.** Installation of the fascia flashing, shown in figure 131, is done by first installing the tar stop. The bottom strip is installed on the wood fascia. Next, piece A of the expansion joint (fig. 132) is installed. Make sure the ¼-inch expansion allowance is made. Apply plastic roofing cement (mastic) in accordance with instructions on the working drawings (figs. 131 and 132). Install a length of fascia flashing (straight or corner pieces) between pieces A of two expansion joints. Then install piece B of the expansion joint by inserting the 1-inch pocket over the bottom strip. Fit piece B over the fascia and roof deck. The screw holes in piece B should line up with the screw holes in piece A. Drill holes in the roof deck for number 10 x 1¾" wood screws, and install the screws.

21-18. The next part of the installation is to join the 8-foot joints of fascia. To do this, fit the grooved seam pockets on the ends of the sheets and the 1-inch pocket on the bottom edge. After the grooved seam is hooked, flatten it with a mallet and solder it. The metal has already been tinned, so soldering will not be difficult. To solder the seam, apply flux, and sweat-solder the seam with a fire-heated copper. It will probably be necessary to apply some 50/50 bar solder to the seam as the soldering is done. The entire length of the seam should be sweat-soldered to insure that it won't leak. Copper requires a considerable amount of heat when it is soldered; therefore, you will want to change coppers often.

21-19. The remaining pieces of fascia flashing are installed as explained in the preceding paragraphs. Make sure all the solder joints are made watertight and that roofing mastic is applied at each expansion joint.

21-20. **Repair of Flashing.** Repair of flashing may involve the making of new flashing or patching with solder or plastic roofing cement. Copper flashing can usually be repaired by resoldering a seam or spot-soldering a hole in the flashing. To solder copper, clear the spot with a wire brush or emery cloth so that the surface will be bright. Apply the flux, and solder the hole with 50/50 bar solder. If a large hole in copper flashing should need repairing, clean the area to be soldered, apply a flux, tin the surface, make a patch from copper, and solder the patch over the hole.

21-21. Flashing made of galvanized iron is usually repaired by replacing the damaged metal. When replacement is required, remove the old flashing and make a new piece like the old one. When replacing the new piece, make sure that all joints are sealed with roofing cement.

21-22. Base flashing damage is usually caused by nails working loose and the metal separating from the roof. If this occurs, apply roofing cement under the flashing, and renail the flashing to the roof. After renailing, a thin layer of roofing cement should be applied around the edge of the flashing.

21-23. Most metal flashing will last for long periods of time if installed and maintained properly. You will find that most repairs will be caused by nails or other fasteners working loose.

22. Gutters and Downspouts

22-1. Gutters and downspouts are installed on buildings to handle the flow of water discharged from a roof. They may be made from galvanized iron, stainless steel, copper, or aluminum. Figure 134 shows the components of a gutter and downspout system which are installed on a building.

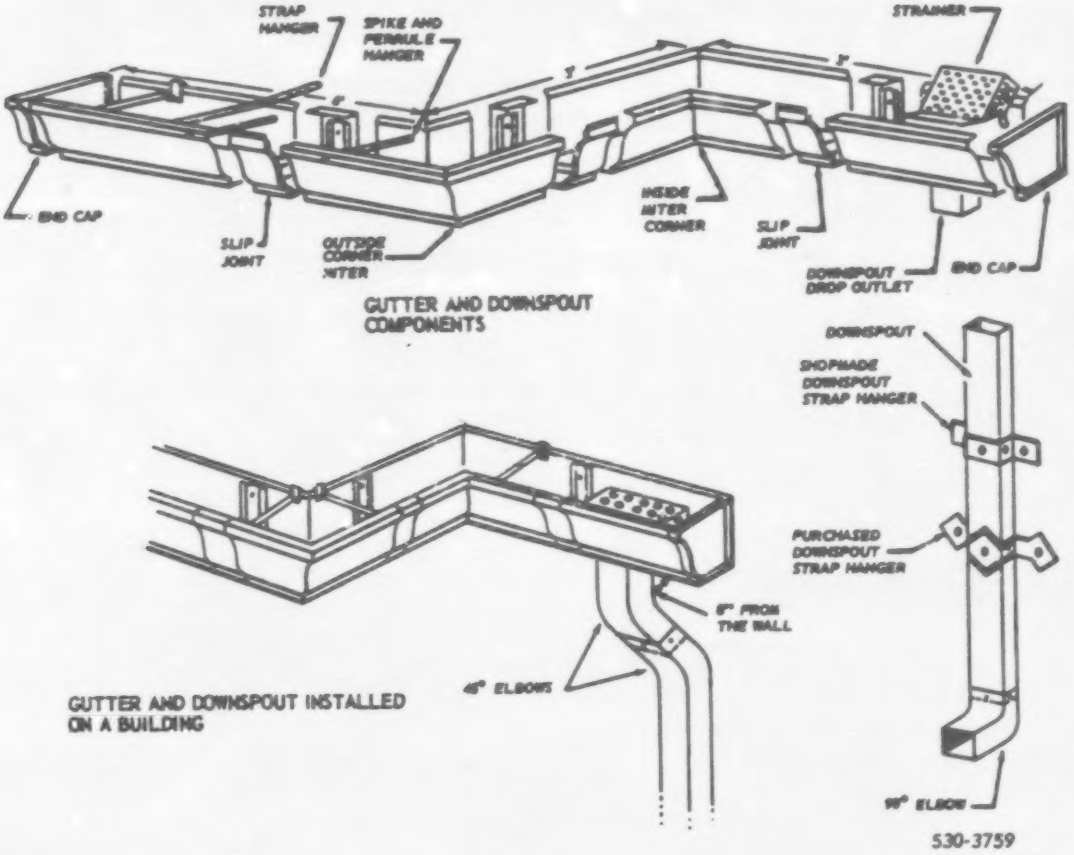

STRAP HANGER
SPIKE AND FERRULE HANGER
6"
3'
3'
STRAINER
END CAP
SLIP JOINT
OUTSIDE CORNER MITER
INSIDE MITER CORNER
SLIP JOINT
DOWNSPOUT DROP OUTLET
END CAP
GUTTER AND DOWNSPOUT COMPONENTS
DOWNSPOUT
SHOPMADE DOWNSPOUT STRAP HANGER
PURCHASED DOWNSPOUT STRAP HANGER
6" FROM THE WALL
45° ELBOWS
GUTTER AND DOWNSPOUT INSTALLED ON A BUILDING
90° ELBOW
530-3759

Figure 134. Gutter and downspout components.

22-2. **Gutter Shapes.** Gutters are made in several different shapes (usually to the specification on the working drawings) to fit special needs. Figure 135 shows four basic shapes of gutters, from which many variations are possible. Box gutters are made in several shapes. The ogee box gutter is often used on buildings and can be purchased in standard sizes, such as 4-, 5-, and 6-inch widths and in 10-foot lengths. The width is the distance across the top. The box gutter with a single bead is usually shop made, and the length is determined by the requirements of the job. However, the lengths that can be made will be determined by the length of the cornice brake in your shop. Joints 10 feet long are probably the maximum lengths that can be made in your shop. Half-round gutters, like the ones shown in figure 135, may have a single bead or a double bead on the edges. The beads add strength to the gutter and improve the appearance. Half-round gutters can also be purchased in standard sizes such as 4-, 5-, 6-, and 7-inch widths and 10-foot lengths.

22-3. **Gutter Components.** Other components used with straight joints of gutter consist of several parts such as slip joints, end caps, corner miters, hanger parts, strainers, and downspout drop outlets.

22-4. *Slip joints.* Slip joints are used to join straight sections and corner miters. They may be made of galvanized iron, stainless steel, copper, or aluminum and can be purchased or made in the shop. The joint connection should match the size and shape of the gutter that is being used. When using slip joints to join gutters, the sealing cement should be of the nonhardening type. Slip joints, such as those shown in figure 134, will allow for expansion and contraction of the gutter when the temperature changes.

22-5. *End caps.* End caps are used as plugs at the ends of gutters. These caps are sometimes called *friction caps,* because the edges are folded into a pocket similar to the pocket of a standing seam. This pocket can be seen on the right end cap shown in figure 134. On galvanized and copper gutters, the caps are soldered during installation. On aluminum gutters the caps are sealed with a plastic cement compound during installation. End caps can be purchased or made to fit the gutter that is being installed.

22-6. *Corner miters.* Inside and outside corner miters are shown in figure 134. These miters can be purchased in standard sizes for box and half-round gutters. Purchased corner miters are usually 6 inches long on each side of the turn. They are joined to the gutter with slip joints, or they may be lapped, riveted, and sealed. If the joints are lapped, the lap should be in the direction of flow. The lap should be at least 1 inch to insure a strong joint.

22-7. *Hangers.* Hangers, such as those shown in figures 134 and 136, are used to support and hang box gutters and half-round gutters. The hanger shown in view A of figure 136 acts as a hanger and brace. Two parts make up this hanger: the hanger and fastener strap. The hanger is nailed to the fascia board and into the rafter; then the gutter is slipped under the back lip of the hanger and fitted into place. The slot in the fastener straps is then hooked over the front lip on the hanger and snapped over the bead of the gutter, as shown in the illustration.

22-8. Ferrules and spikes, such as shown in view B of figure 136, are used to hang gutters. The ferrule length is determined by the size of the gutter being installed, and the length of the spike is determined by the ferrule length. For example, a 4-inch ferrule should have a 7-inch spike because the spike should extend through the ferrule approximately 3 inches so that the spike will be held securely by the wood rafter. To install a ferrule and spike, insert the ferrule between the gutter beads, and drive the spike through the outside gutter bead, ferrule, back side of gutter, and fascia and into the rafter. When a ferrule is installed, it should look like the one shown in view B of figure 136.

22-9. The hanger shown in view C of figure 136 is for a single-bead half-round gutter. Notice that it is made in two parts—the hanger and a half-circle brace—and is fastened with nails to the fascia board and rafter. The part that fastens to the wood has several vertical holes for height adjustment. The half-circle brace for single-bead half-round gutter can be used with several other types of gutter hangers, as shown in views C, D, and E. Notice that the hanger in view D is nailed under the shingles. A hanger such as this is made for the pitch of the roof so that the half-circle brace will hold the gutter level. The hanger in view E is adjustable and is used when the roof has a pitch and the hanger is being installed under the eave. View E shows how the hanger is adjusted to the roof pitch. The half-circle brace shown in view D is for a double-bead half-round gutter. It has a lip on the back of the brace.

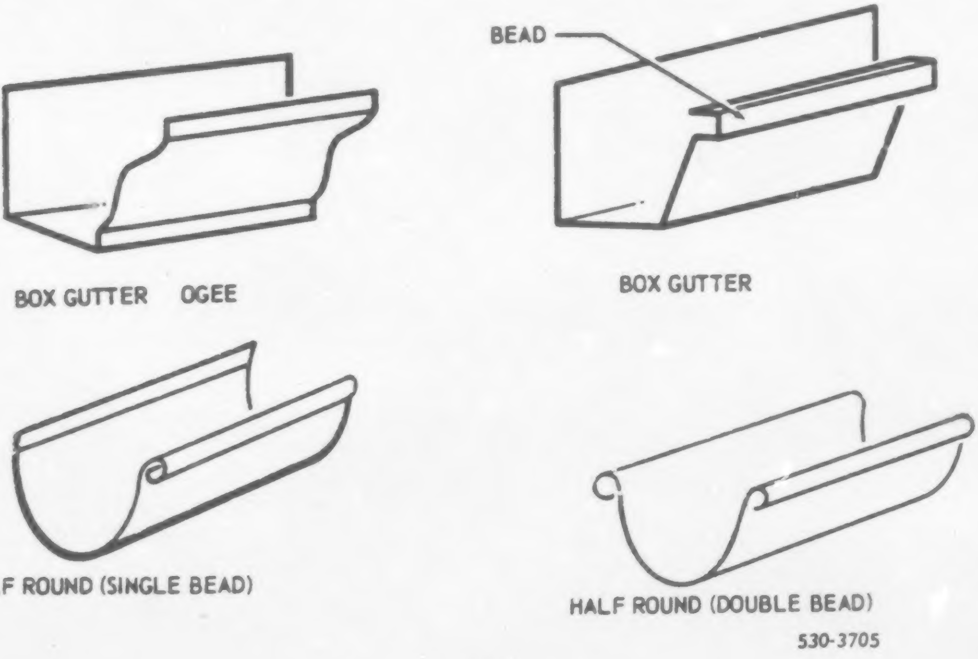


Figure 135. Gutter shapes.

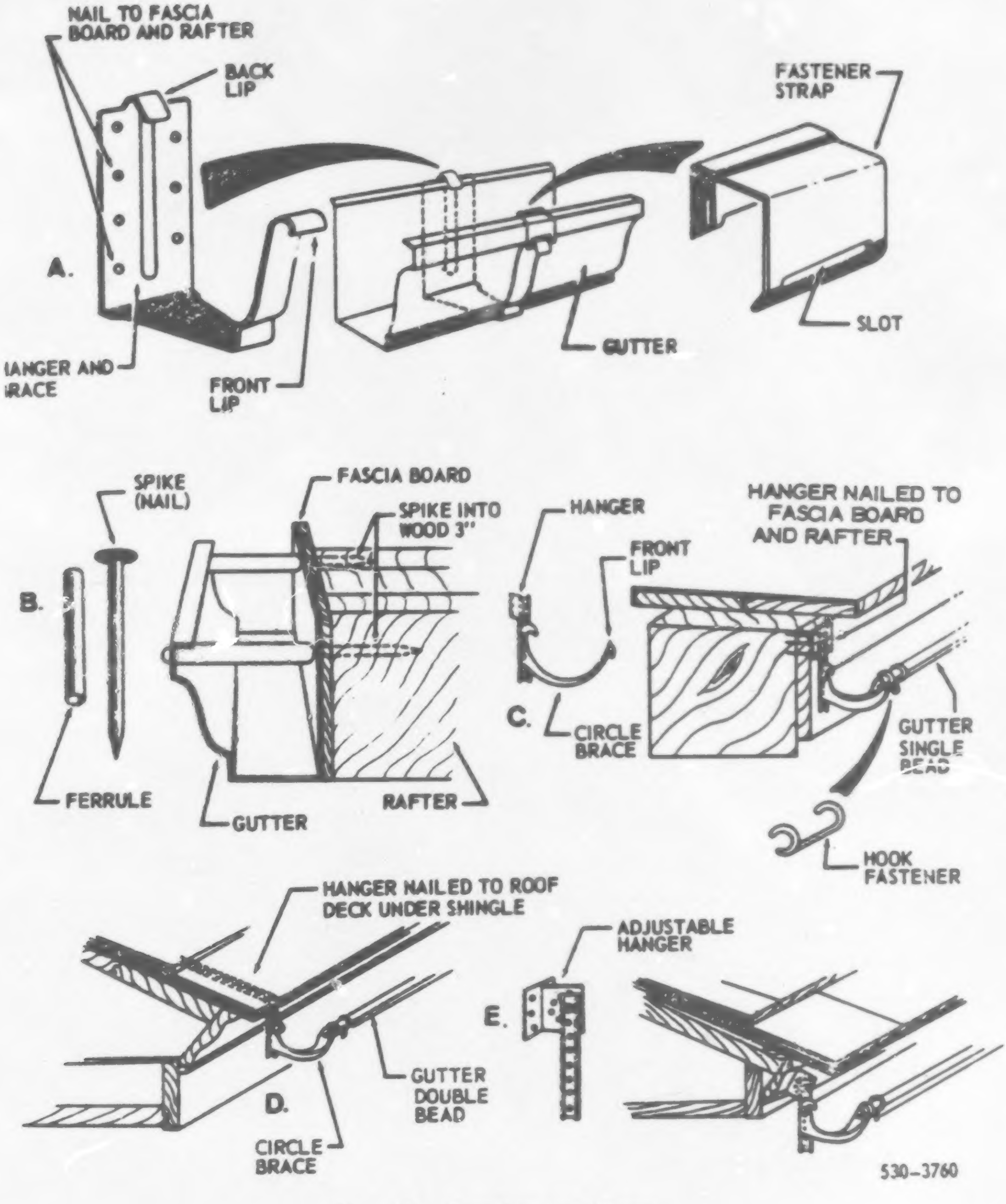

NAIL TO FASCIA BOARD AND RAFTER
BACK LIP
A.
IANGER AND
IRACE
FRONT LIP
GUTTER
FASTENER STRAP
SLOT
B.
SPIKE (NAIL)
FERRULE
FASCIA BOARD
SPIKE INTO WOOD 3"
GUTTER
RAFTER
HANGER
FRONT LIP
C.
CIRCLE BRACE
HANGER NAILED TO FASCIA BOARD AND RAFTER
GUTTER SINGLE BEAD
HOOK FASTENER
HANGER NAILED TO ROOF DECK UNDER SHINGLE
D.
GUTTER DOUBLE BEAD
CIRCLE BRACE
ADJUSTABLE HANGER
E.
530-3760

Figure 136. Gutter hangers and braces.

22-10. Other hangers, such as the strap hanger in figure 134, may be used to hang gutters. Strap hangers may be shop made or purchased; they are nailed to the roof deck and bolted to the bead on the gutter. When this type of hanger is used, a brace is also used for additional strength.

22-11. *Strainers.* Strainers, such as the one shown in figure 134, can be shop made or purchased. A strainer should be installed at each downspout drop to prevent the downspout from being clogged with leaves or trash. The strainer should be made so that it can be easily removed for cleaning. The strainer shown in figure 134 is made so that it is wedged into the gutter.

22-12. *Downspout drop outlets.* Downspout drop outlets like those shown in figures 134 and 137 are fastened to the flat bottom gutters. The oval shape in view A of figure 137 can be used with square or round downspouting. The downspout outlet shown in view B is for square downspouting only. The round downspout outlet shown in view C is for round downspouting only and is used with half-round gutter. Notice that all of the outlets taper so that the downspout pipe will fit over the outlet. When making a drop outlet in the shop, you should make it about ⅛ inch smaller so that the downspout will fit over the outlet. To fasten the downspout drop outlet to the bottom of a gutter, the flanges are soldered on the inside of galvanized gutters. For copper gutters, the flange is riveted to the gutter and then soldered. On aluminum gutters, the flange can be soldered or riveted. Where the flange is riveted, plastic cement should be used.

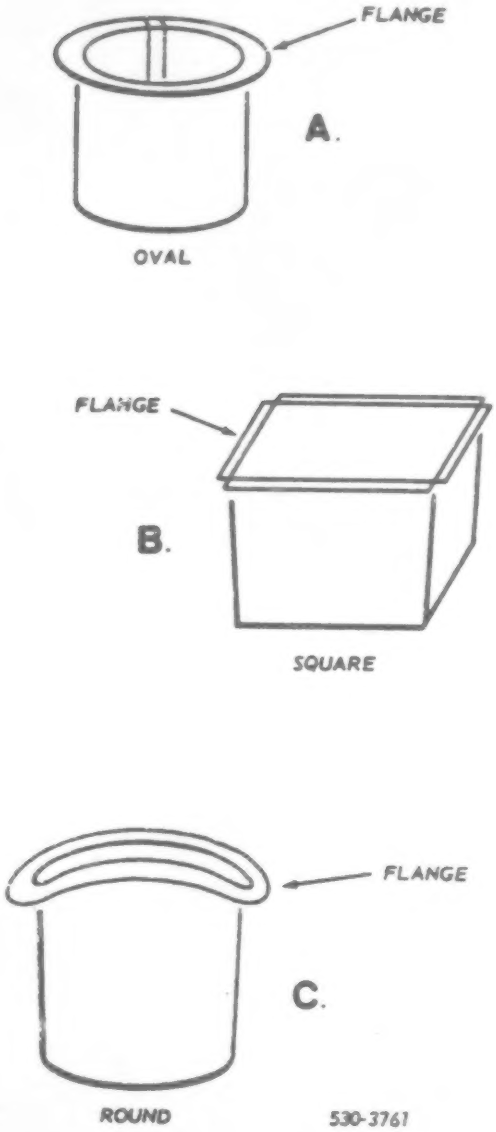


Figure 137 Downspout drop outlets.

22-13. **Downspouts.** Downspouts are used to route water from a gutter to the bottom of the building. They are also called conductor pipe or rain pipe. Some downspouts can be purchased more cheaply than they can be made if special equipment is not available in the sheet metal shop. However, it is possible to make square- or rectangular- shaped downspouts in most shops. Downspout shapes and sizes such as those shown in figure 138 are available. Plain rectangular downspouts are usually 2" x 3" or 3" x 4"; square corrugated downspouts are available in 2-, 3-, 4-, and 5-inch sizes; round corrugated downspouts are available in 2-, 3-, 4-, 5-, and 6-inch sizes; and plain round downspouts are available in 1½-, 2-, 3-, 4-, 5-, and 6-inch sizes. The standard length of these conductors is 10 feet.

22-14. The material from which these downspouts are made will depend on the material used for the gutter. This is why most downspout components are available in galvanized iron, stainless steel, copper, or aluminum. The corrugated downspouts are normally used in localities where the water may freeze in the conductor. The corrugations allow for expansion when water freezes. Under freezing conditions, plain downspouts may rupture because there is no provision for expansion of the pipe.

22-15. Downspout components such as straight joints, elbows, and hangers are shown in figure 134. The elbows are used to make offsets and turns in the routing of the downspout. Elbows are available in different angles, such as 30°, 45°, 60°, and 90°. Notice that there are no sharp turns where the elbows are used. Sharp turns should be avoided so that a smooth flow will be obtained. The elbow at the bottom of the downspout is sometimes called a *shoe*; it turns the water away from the building. A concrete pad should be placed at this outlet to avoid washing soil away from the building.

22-16. Strap hangers are used to support the conductor. They may be readymade, or they may be made in the shop from galvanized iron, stainless steel, copper, or aluminum. The straps are usually 2 to 4 inches wide and long enough to fit around the downspout and make two flanges for fastening to the wall. The strap han-

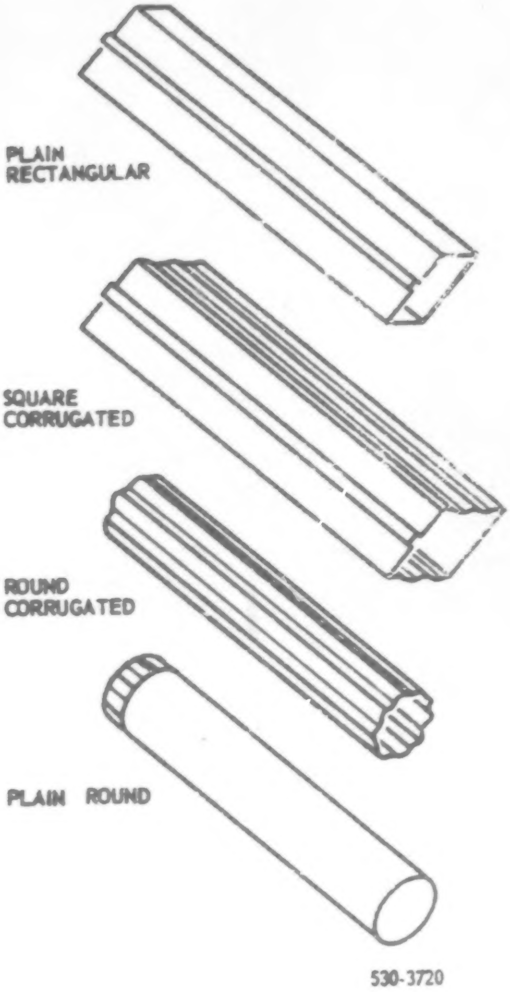


Figure 138. Downspouts.

gers are fastened to the wall with nails, sheet metal screws, or bolts, depending on the material the wall is made of. If the wall siding is wood, nails should be used; if the siding is metal, sheet metal screws should be used; if the wall is masonry, an anchor and bolt should be used. The hangers are fastened to the conductor with sheet metal screws. The spacing for the hangers should be specified on the working drawings; however, if not specified, a good rule to follow is two hangers for each 10-foot joint of downspout.

22-17. **Installation of Gutters and Downspouts.** Installation of gutters and downspouts is done as specified on the working drawings. The following is a typical specification that you may find on a working drawing:

> Gutters are to be installed with the high end opposite the downspout so the water will flow to the downspout outlet. Hangers are to be installed not more than 30 inches apart on center. Expansion joints should be located at 40-foot intervals for 16-ounce copper and at 48-foot intervals for 20-ounce (and thicker) copper. When the gutter is aluminum with a thickness of 0.032 inch, the expansion joint should be at 32-foot intervals; it should be at 40-foot intervals for 0.040 inch or thicker.

22-18. Specifications for the installation of downspouts will also require that slip joints telescope 1½ inches in the direction of flow. These joints should be fastened with sheet metal screws and soldered. The downspout should be plumb with the wall and straps used to hold it away from the wall. The straps should be fastened to the downspout with three screws and to the wall with two screws, as shown in figure 134.

22-19. *Gutter installation.* To see how installation specifications are applied, let us see how the gutter shown in figure 134 is installed. Suppose this gutter is to be installed over a building entrance that is 6 feet across the front, is 3 feet between corner miters, and extends 3 feet from the inside corner miter to the end. The gutter is galvanized iron and was purchased readymade. The gutter is to be hung with hangers like the one shown in view A of figure 136.

22-20. Start the installation by making a chalk line on the fascia board. The chalk line should be started on the end opposite the downspout location with the chalk line held as close to the eave overhang as possible. On the other end, lower the chalk line ¼ inch so that the gutter will have enough drop to allow the water to flow toward the downspout. Pull the line straight out and release it to make a straight chalk mark. This is the chalk line for the 6-foot side of the front entrance shown in figure 134. Next, place one end of the chalk line on the ¼-inch mark at the outside corner, and stretch the line to the inside corner, lowering it ¼ inch more. Pull the string tight and make another chalk mark. The last chalk line will be made from the inside corner to the end of the gutter where the downspout is located. Make this chalk line with another ¼-inch drop.

22-21. The hangers can now be installed by nailing the first hanger about 3 inches from the high end of the gutter. Make sure the top of the hanger is placed on the chalk line. The next hanger is installed 3 inches from the outside corner. Since specifications require hangers on no more than 30-inch centers, install two hangers 22 inches apart between the end hangers. Next, the hangers between the outside corner and inside corner can be installed 3 inches from the corners. The next hangers to be installed are between the inside corner and the outlet end of the gutter. One hanger is 3 inches from the inside corner, and one is about 2 inches from the gutter end. Don't place the end hangers too close to the end caps.

22-22. Installation of the inside corner miter is next. Place it in the hanger with the top edge on the back of the gutter under the lip on the hanger. Apply mastic (plastic cement) in the pockets of the two slip joints with a putty knife, and install the slip joints on each end of the inside corner miter. Install the outside corner miter the same way. Next, measure the distance from the bottom of the pockets on the two corner miters. This measurement should be close to 23 inches because the slip joints should have a ½-inch spacer. Cut a piece of the straight gutter to 23 inches, remove the outside corner miter, and slip the straight piece into the pocket at the inside corner miter. Now, reinstall the outside corner miter by slipping its slip joint pocket over the edge of the straight gutter piece. The snap locks can now be installed on the hangers to hold the gutter in position.

22-23. The front gutter can not be installed. First, measure from the pocket of the slip joint (at the outside corner miter) to the end of the building. This measurement should be close to 65½ inches and should be used when cutting the piece of straight gutter. Cut the gutter and install the end cap (with solder) to this straight gutter; install the gutter by placing the back edge under the lip on the hangers and pressing down on the front of the gutter. Slide this straight gutter into the outside corner slip joint, and install the snap locks on the hangers.

22-24. The last piece of gutter to install is the straight piece with the downspout drop outlet. Begin by cutting a piece of straight gutter 29½ inches long. Measure 6 inches from the outside edge for the center of the drop outlet. Cut a hole for the drop outlet, install the drop outlet (with the flange inside), and solder around the flange. With the outlet and end cap soldered in place, the gutter is ready to install in the hangers. Do this by inserting the gutter back edge under the lip on the hangers, pushing down on the front, slipping the edge into the slip joint, and installing the snap locks. Check all slip joints to see that they are well sealed. Apply mastic where necessary.

22-25. *Downspout installation.* In the previous paragraphs we have explained the installation of the gutter shown in figure 134. Now let us see how its downspout is installed. Measure the distance from the bottom of the gutter (top of the drop outlet) to the ground. Assume that this measurement is 11 feet 6 inches and that one 10-foot length of straight downspout is needed plus three elbows—one 90° and two 45°. Assemble the elbows and straight joint as shown in figure 134. (In this case, the assembled downspout is short enough to be held up in place to check the fit.) Fasten the pieces together with sheet metal screws, and solder the joint connections. Position the assembled downspout with the upper elbow fitting over the gutter drop outlet, fasten with sheet metal screws, and install three strap hangers to support the downspout.

22-26. **Minor Repair of Gutters and Downspouts.** Repair of gutters and downspouts will usually consist of minor repairs, such as resealing joints and refastening hangers. (Major repair includes the replacement of gutters and downspout components.) Before resealing joint connections with mastic, remove the old mastic so that the outside edges of the joint are clean. New mastic is applied with a putty knife or calking gun. Resoldering of seams will require that the seams be cleaned (heating the solder and wiping it with a clean, dampened cloth, applying flux, and tinning the seam). After the seam is cleaned, it can be soldered with a well-heated copper and bar solder. Small holes in gutters and downspouts can be easily repaired with solder, as you learned earlier in this chapter when making repairs on metal roofs. Larger holes, however, may require that a patch be made and installed. Hangers that have pulled loose may be refastened with sheet metal screws, nails, or bolts. If a hanger is missing, a new one should be made to match others.

22-27. When small holes are found in gutters or downspouts, you should carefully examine the damaged areas for evidence of corrosion (rust). To detect these areas, look for spots where the rust is showing. You should be able to see rust scales if a spot is bad. Pits will also show in the metal where corrosion is beginning to take hold. On gutters that have been painted, corrosion can occur under the paint. In some cases, this may be only a bubble on the surface with a small pin hole that reveals only a small area of corrosion. If the bubble is removed with a putty knife, a large area of rust may be exposed. The area should be thoroughly examined to determine how deeply the rust has penetrated. The strength of the metal can be tested by pressing against the corroded surface with the tip of the putty knife blade. If the metal gives way, the damaged metal should be replaced.

22-28. **Replacement (Fabrication) of Gutters and Downspouts.** To replace all or portions of gutters or downspouts, you must determine what is to be made and what material is to be used. You should make a sketch of the gutter and downspouts to include dimensions and shape.

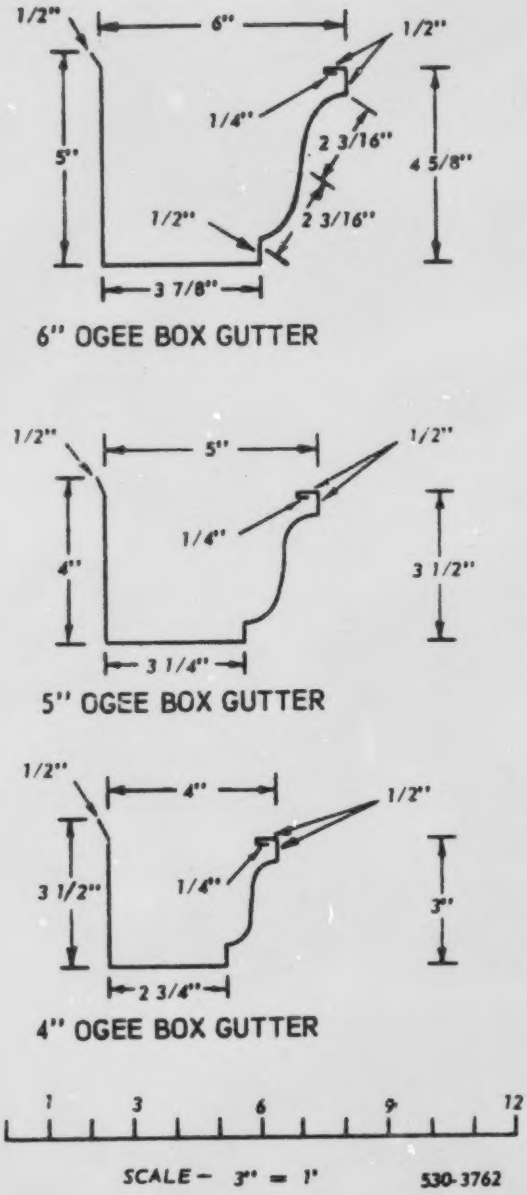


Figure 139. End views of ogee box gutters.

After the sketch is made with all of the necessary measurements, you can return to the shop to begin the fabrication of the replacement pieces.

22-29. *Straight gutter.* For this example, assume that you are to fabricate two 10-foot joints of 6-inch ogee box gutter, like that shown in figure 139. A downspout drop outlet 2⅜″ x 2⅞″ x 3″ long is to made for a 2½″ x 3″ downspout. A sheet of galvanized iron 4′ x 10′ will be enough metal to make the gutter and the downspout in this example. First, develop a pattern for the ogee gutter like the one shown in view A of figure 140. The length of the sheet is 10 feet and the pattern is 10 feet, so the 15-inch stretchout should be cut lengthwise from the sheet. Notice in view B of figure 140 that the bends are numbered and correspond to the numbers on the pattern. The bend lines should be prick-punched on the metal so that they can be easily seen from either side of the metal during the forming.

22-30. Before forming the pattern on the cornice brake, make sure that the machine is correctly set for bending 26-gage metal. (If necessary, refer to the cornice brake illustrated in Vol. 2 for the following checks.) Check the clamping pressure to see if it is tight enough for 26-gage metal and that the pressure is the same on each end of the brake. This pressure should be great enough to hold the metal firmly when bends are being made. Next, check the setback and bend allowance for the top leaf. Each end of the brake should have the same distance between the top nose bar and the bending leaf. Since sharp bends are to be made, this distance should be 1½ to 2 times the thickness of the metal. Make certain the top leaf is adjusted correctly so that an even bend will be made on each end of the brake.

22-31. With the pattern made and the cornice brake adjusted, the 6-inch ogee box gutter can be formed. The bends are made in the order shown in figures 140 and 141. Place the metal in the brake and make the number 1 bend 30°. Turn the pattern around and make the number 2 bend 160°; then remove the metal from the brake and flatten it to 180°. Make the number 3 bend 90° at the 1-inch mark on the same side of the sheet. Make the number 4 bend by turning the metal over and bending the metal 90°. Now, repeat each of these steps for the second pattern because bend 5 will require that the ogee former be installed on the brake.

22-32. The former shown in bend 5 of figure 141 is installed by placing the former on the bending leaf and installing the clamps. Use a mallet to set the clamps tightly so that the former will be held firmly to the bending leaf. To make bend number 5, insert the metal under the top leaf as far as the number 4 bend. With the metal clamped in place, grasp the metal with your hands, spread it about 24 inches apart, and pull it down until it is parallel with the bed, as shown for bend number 5. Take the metal out of the brake, turn it over, clamp the 1-inch flange under the top leaf, and pull the metal down with your hands to make bend number 6. Make these two bends (numbers 5 and 6) on both pieces of metal so that the former can be

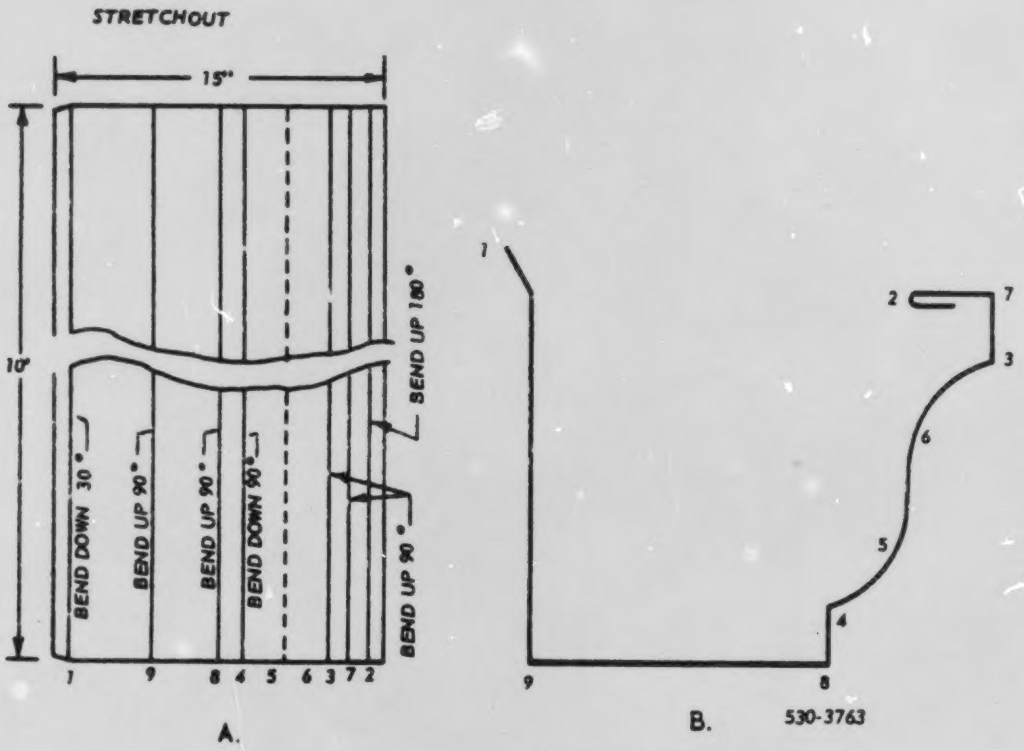


Figure 140. Pattern and shape for ogee box gutter.

removed. Remove the former and continue with bends 7, 8, and 9. Make the number 7 bend 90° as shown in figure 141. Turn the metal around and make the number 8 bend 90°. Make the number 9 bend 90° to complete the forming of the first pattern. Make bends 7, 8, and 9 on the second pattern to complete the forming of the two pieces of gutter.

22-33. *End caps.* The remaining gutter components can now be fabricated. Start with the left and right end caps and develop a pattern like the one shown in view A of figure 142. Make the seam allowances and notching instructions as shown in the illustration. Form the ½-inch flanges on the three sides that are not notched. This is done on the cornice brake by starting with the 3⅞-inch bottom flange. After the first bend is made, let the flange extend past the top leaf as the metal is clamped (to prevent damaging the flange). The notched tabs can be formed on the end of a conductor stake and square stake. Use a tinner's riveting hammer and bend the curved edge on the conductor stake and the flat edge on the square stake. Remember to bend one cap for the left end and one cap for the right end.

22-34. *Drop outlet.* The next component to make is a downspout drop outlet, such as that shown in view C of figure 142. Make the pattern with a ⅜-inch flange allowance across the top and ½-inch allowance for the 5/16-inch grooved seam. Form the grooved seam on the cornice brake, or Pittsburg lock forming machine, as shown in view D. Notice that the seam will be on the back side when the outlet is installed. Next, bend the ⅜-inch flanges for all sides except the back, which should remain straight. Make these bends on the square stake by placing the bend line on the edge of the stake and striking the flange with a tinner's riveting hammer.

22-35. Fit the left end cap on one gutter joint and the right end cap on the other joint. Fasten the bottom flange with two rivets and the back flange with three rivets. Install a ⅜-inch number 6 sheet metal screw in the flange on the top edge of the bead, and solder the cap with 50/50 bar solder. Be sure to cover the rivets and screwhead and sweat the solder into the lap seam. Next, the drop outlet is installed on the gutter piece with the left end cap. Locate the center of the drop outlet 6 inches from the left end and cut a hole. Make a starter hole with a ½-inch cold chisel, and cut the rectangular

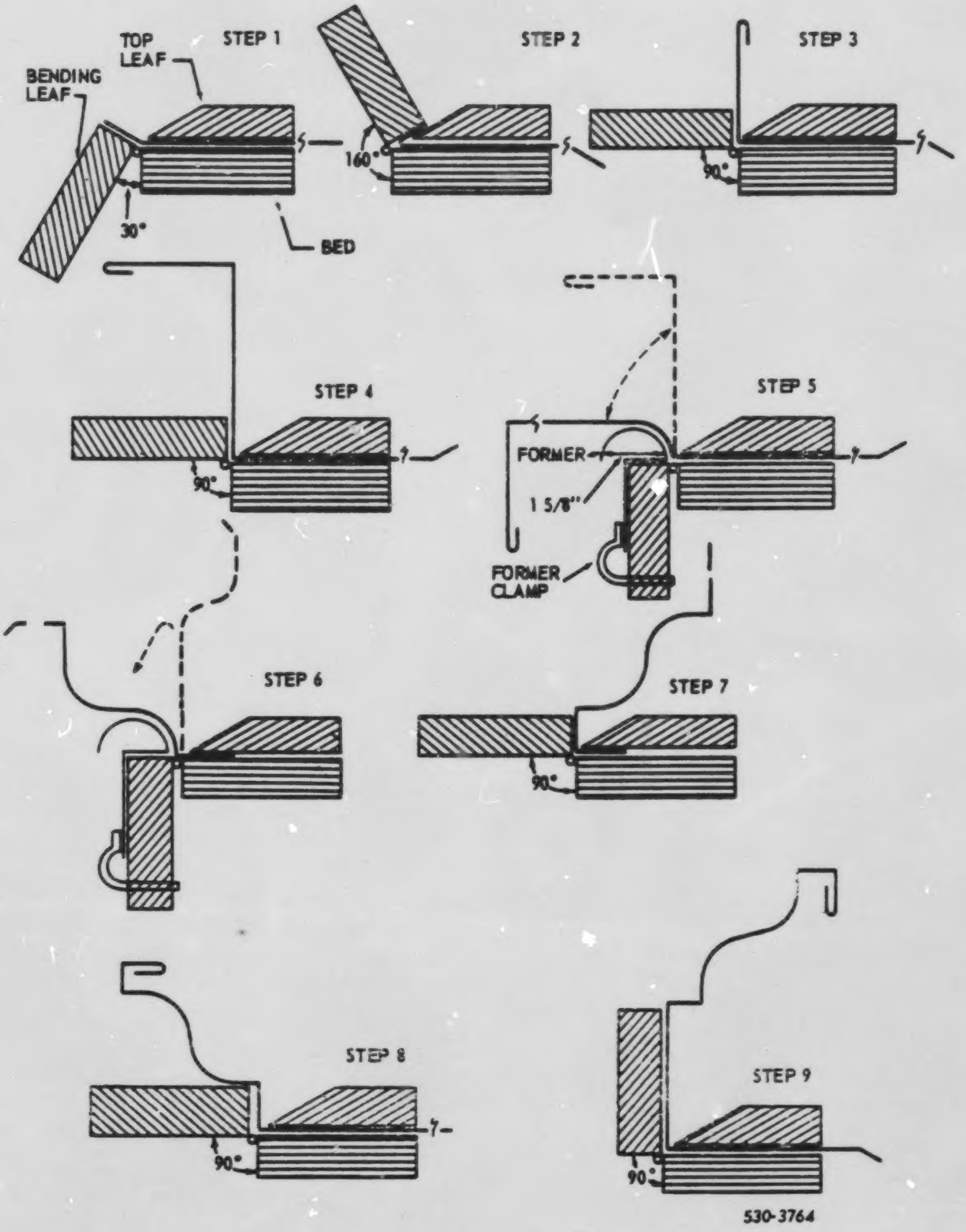

STEP 1
TOP LEAF
BENDING LEAF
BED
30°
STEP 2
160°
STEP 3
90°
STEP 4
90°
STEP 5
FORMER
1 5/8"
FORMER CLAMP
STEP 6
STEP 7
90°
STEP 8
90°
STEP 9
90°
530-3764

Figure 141. Forming ogee box gutter on the cornice brake.

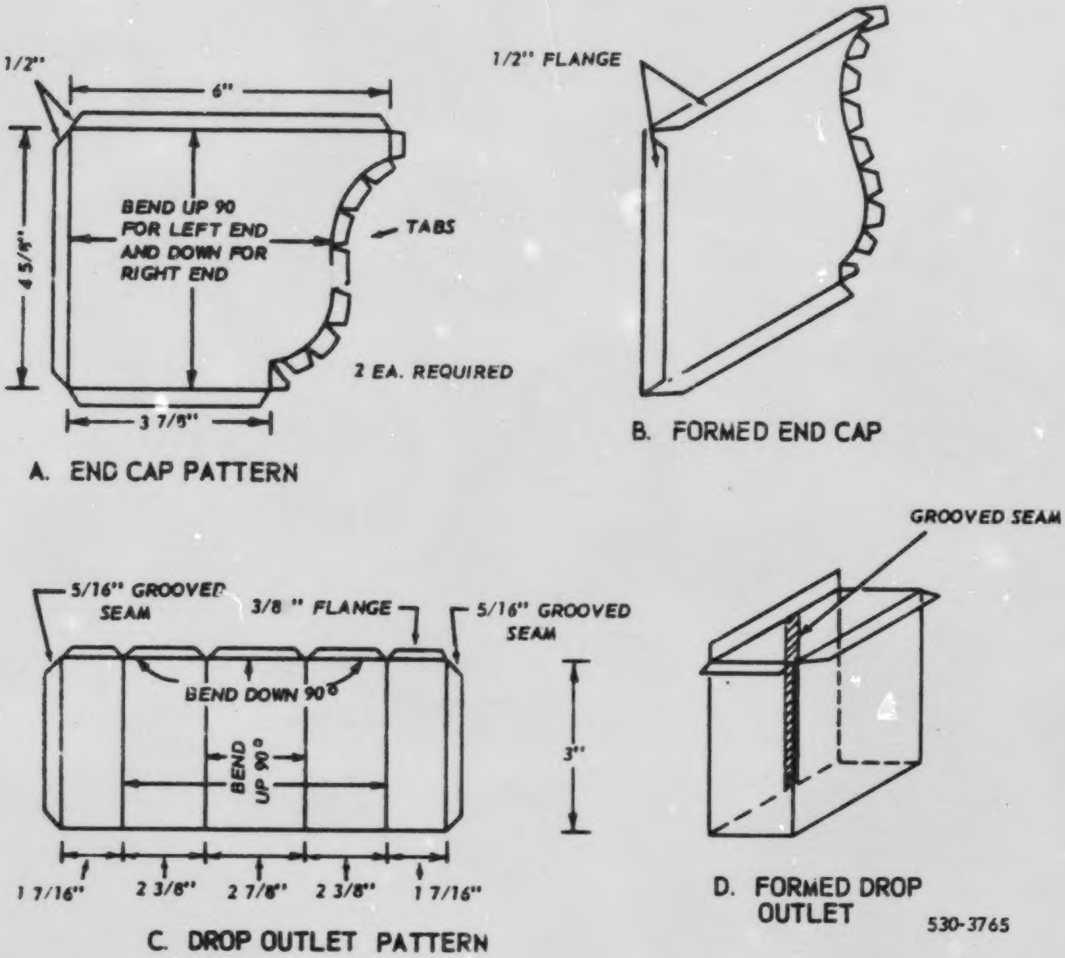

1/2"
6"
4 5/8"
BEND UP 90
FOR LEFT END
AND DOWN FOR
RIGHT END
TABS
2 EA. REQUIRED
3 7/8"
A. END CAP PATTERN
1/2" FLANGE
B. FORMED END CAP
5/16" GROOVED
SEAM
3/8 " FLANGE
5/16" GROOVED
SEAM
BEND DOWN 90°
BEND
UP 90°
3"
1 7/16"
2 3/8"
2 7/8"
2 3/8"
1 7/16"
C. DROP OUTLET PATTERN
GROOVED SEAM
D. FORMED DROP
OUTLET
530-3765

Figure 142. Patterns for gutter parts.

shaped hole with aviation snips. Insert the drop outlet down through the opening, and rivet it into place. Solder around the flanges and rivet heads.

22-36. *Slip joints.* The next component to fabricate is a slip joint, such as the one shown in view D of figure 143. The outside piece shown in view A has the same shape and stretchout as shown in figure 140, except that the stretchout dimensions should be measured on the *outside* of the gutter. This outside piece of the slip joint will be only 2½ inches wide and is formed on the cornice brake like the long joints except for the curved bends. These bends can be made on the conductor stake by pressing by hand because the material is only 2½ inches wide. The inside piece of the slip joint (view B of fig. 143) is made by using the *inside* measurement of the gutter and making a stretchout pattern that is 2½ inches wide. Notice that this piece does not have the ½-inch flange and the hem that piece A does. This piece can also be formed on the cornice brake and conductor stake. The ½-inch-wide spacer, shown in view C, should be made from 16-gage metal to allow for the sealant and to give sufficient room for a slip joint. The spacer is formed just like piece B. After the three pieces are made, they can be assembled by riveting or spot welding.

22-37. *Corner miters.* Corner miters can be made in a gutter at any point where needed. In this example, we will make the outside and inside corner miters shown in figure 144. Notice that the measurements are 6 feet from the end cap of piece 1 to the throat of the outside corner miter, 3 feet to the heel of the inside corner miter, and 3 feet to the end cap of piece 3. Begin with piece 1 and make a mark, on the back side,

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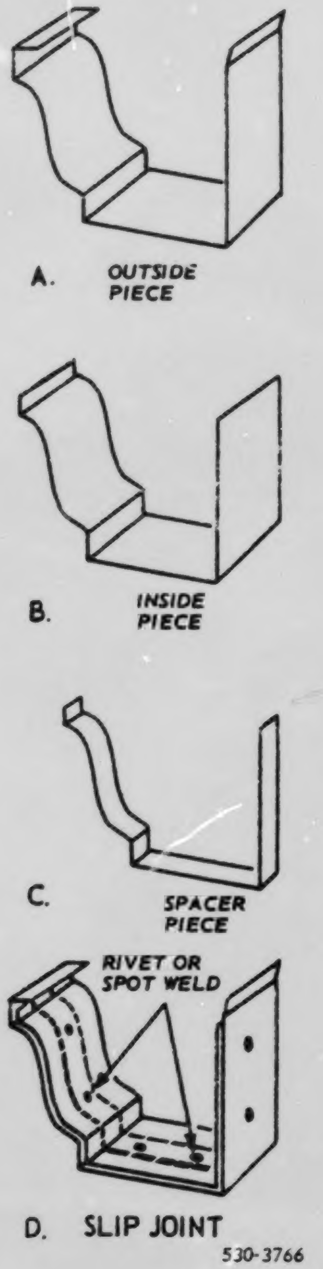

Figure 143. Pieces to fabricate a gutter slip joint.

6 feet from the end cap; then use the 90° side of a combination square to draw a line through the 6-foot mark on the back side. Next, place the 45° angle of the combination square against the back side, and draw a 45° line across the bottom of the gutter. Be sure this angle for piece 1 is the same as shown in figure 144. After marking the 45° miter lines, make a ½-inch allowance on piece 1 for notches on the ogee side and for flanges on the bottom and back sides. Piece 2 is made in a manner similar to that for piece 1 except that one end has a 45° miter without any allowances and the other end has a ½-inch allowance for the tabs and flanges. Be sure to make the miter angles as shown in figure 144. Piece 3 is 3 feet from the end cap to the heel of the inside corner miter. Notice that the 45° miter is plain and does not have tabs or flanges.

22-38. Cut the miters, flanges, and tabs with straight snips and aviation snips. After cutting and notching pieces 1, 2, and 3, bend the back side flanges 90° with a hand seamer. The flange on piece 1 should fit inside of piece 2, and the flange on piece 2 should fit inside of piece 3. Do *not* bend the bottom flanges. Next, bend the tabs 90° with common pliers. The tabs are bent in the same direction as the flanges. Fit the pieces together with the flanges and tabs on the inside of the gutter; then rivet the flanges. Place a sheet metal screw in the top edge of the beads in each corner, as shown in figure 144. The last step is to solder the seams with 50/50 bar solder. Be sure to sweat the solder into the seams and to cover the heads of the rivets and screws.

22-39. *Straight downspouts.* Straight downspouts (without corrugations) can be fabricated from patterns such as the one shown in figure 145. This downspout is 2½" x 3", so the stretchout will be 11 inches plus seam allowances. The downspout will be jointed with a 5/16-inch grooved seam in the center of the 3-inch side; therefore, the ½-inch allowance will be made as shown in view A. After developing two patterns, such as the one shown in view A, cut the patterns on the squaring shears or gap squaring shears, and notch the ends of the seam allowances. Next, run the two sheets through the Pittsburg lock forming machine; then use the cornice brake to make the 90° bends in the 1, 2, 3, 4, order shown in view A.

22-40. Next, the seams are locked and flattened with a mallet. For a bucking bar, place a 6-foot piece of 2" x 2" x ¼" angle iron in a vise with the flat surface up. The metal should extend out of the vise at least 5 feet. Place one of the downspout pieces over the angle iron with the seam up. After flattening 5 feet of the seam, turn the downspout around and flatten the other 5 feet. Do this on both joints of downspout; then make three strap hangers from 16-gage sheet metal. They should look like the hanger shown in view D of figure 145. Cut three pieces of metal 11⅛" x 1½". Mark the metal as shown in view C, and punch the ⅛-inch holes with a Whitney hand punch or rotary punch.

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Next, bend the straps into the shape shown in view D.

22-41. *Offset downspouts.* The top joint of the downspout shown in view B of figure 146 is offset 8 inches from the inside of the drop outlet to the wall of the building; therefore, a 7½-inch offset needs to be made. To do this, make a 45° elbow in two places on the downspout, as shown in view A. One 45° elbow is 6 inches from the end that connects to the drop outlet and the second 45° elbow is 7½ inches from the first elbow. The first 45° elbow is started by notching out a 22½° angle on each side of the 6-inch line. Make sure this first notch is on the seam side of the downspout. Make ⅜-inch allowances for the lap seam flanges in the direction which the water will flow. On the opposite side of the downspout, make the second notch 7½ inches from the center of the first notch. Each notch can be cut out by starting a hole with a ½-inch cold chisel; then the metal is cut with aviation snips. The seam should be cut with a hand hacksaw to prevent damaging the blades of the snips. Each end of the ⅜-inch lap seam allowances should be notched and turned in so that they will slip inside when the downspout is bent into position. The bending is easily done by hand. This changes the two notches to 45° elbows. The two elbows make a 7½-inch offset in the downspout. Sheet metal screws are installed through the sides with the lap seam flanges. The seams and screw heads are soldered to prevent leaks.

22-42. The shoe shown in figure 146 is made by notching the metal on the side opposite the seam to make two 45° bends, as shown in view C. The notches have flanges and are cut and assembled like the offset shown in view B except that both notches are on the same side of the downspout.

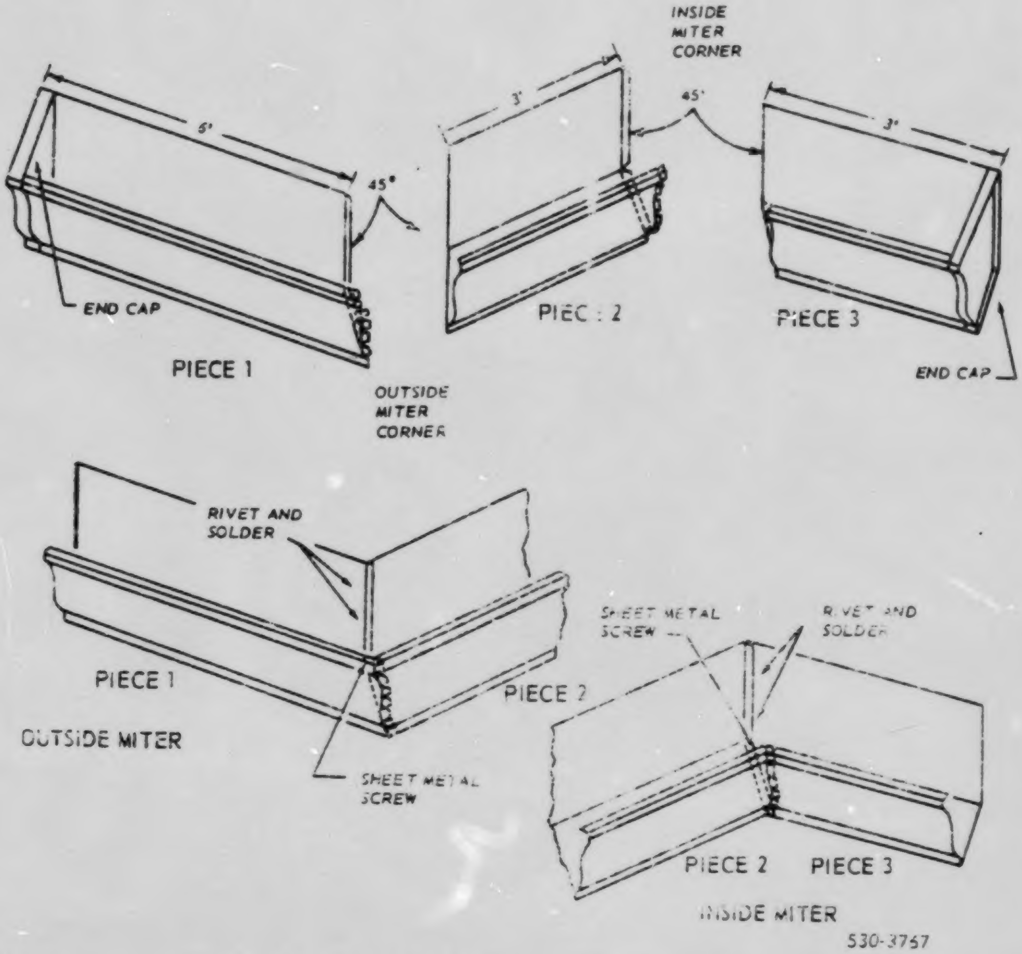
INSIDE MITER CORNER
6'
45°
3'
45°
3'
END CAP
PIECE 1
PIECE 2
PIECE 3
END CAP
OUTSIDE MITER CORNER
RIVET AND SOLDER
PIECE 1
PIECE 2
OUTSIDE MITER
SHEET METAL SCREW
SHEET METAL SCREW
RIVET AND SOLDER
PIECE 2
PIECE 3
INSIDE MITER
530-3757

Figure 144. Making [illegible]

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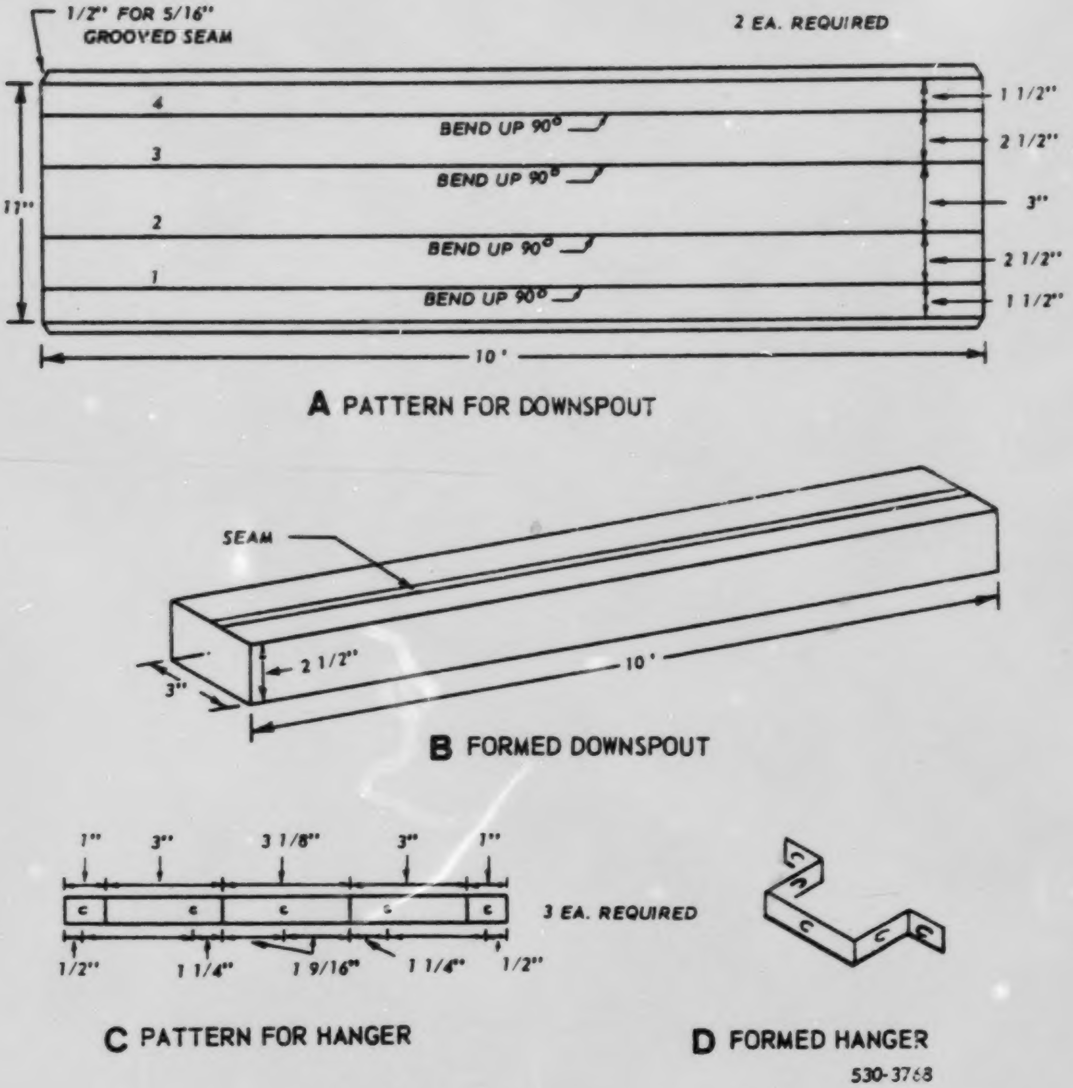

A PATTERN FOR DOWNSPOUT

B FORMED DOWNSPOUT

C PATTERN FOR HANGER

D FORMED HANGER

Figure 145. Making downspouts and hangers.

22-43. **Installation of Replacement Gutters and Downspouts.** In this example we are installing the replacement downspout and gutter fabricated in the previous paragraphs. Since the hangers for the gutter are still on the building, all we have to do to install the gutter is to place the gutter in the hangers and insert the snap locks. After the gutter is installed, you should pour some water into the high end to see if the water flows to the outlet on the low end. The drop should be enough to allow the water to flow out of the gutter. If it does not, reposition the hangers.

22-44. With the gutter in place, the next job is to install the replacement downspout. First, install the upper section (with the offset) over the drop outlet and install sheet metal screws in the three outside surfaces of the downspout. Install the strap hanger just below the second offset. Next, measure from the bottom of the installed downspout to 3 inches above the ground level. This measurement, plus 1½ inches for a joint connection, is the length of the lower section of the downspout. Cut a small notch in each corner of the upper downspout to make a slip joint. After slipping the lower piece of downspout over the upper downspout, install sheet metal screws in three sides of the slip joint. Next, install a hanger just above the shoe and another halfway between the top and bottom hangers. This completes the fabrication and installation of a gutter and downspout.

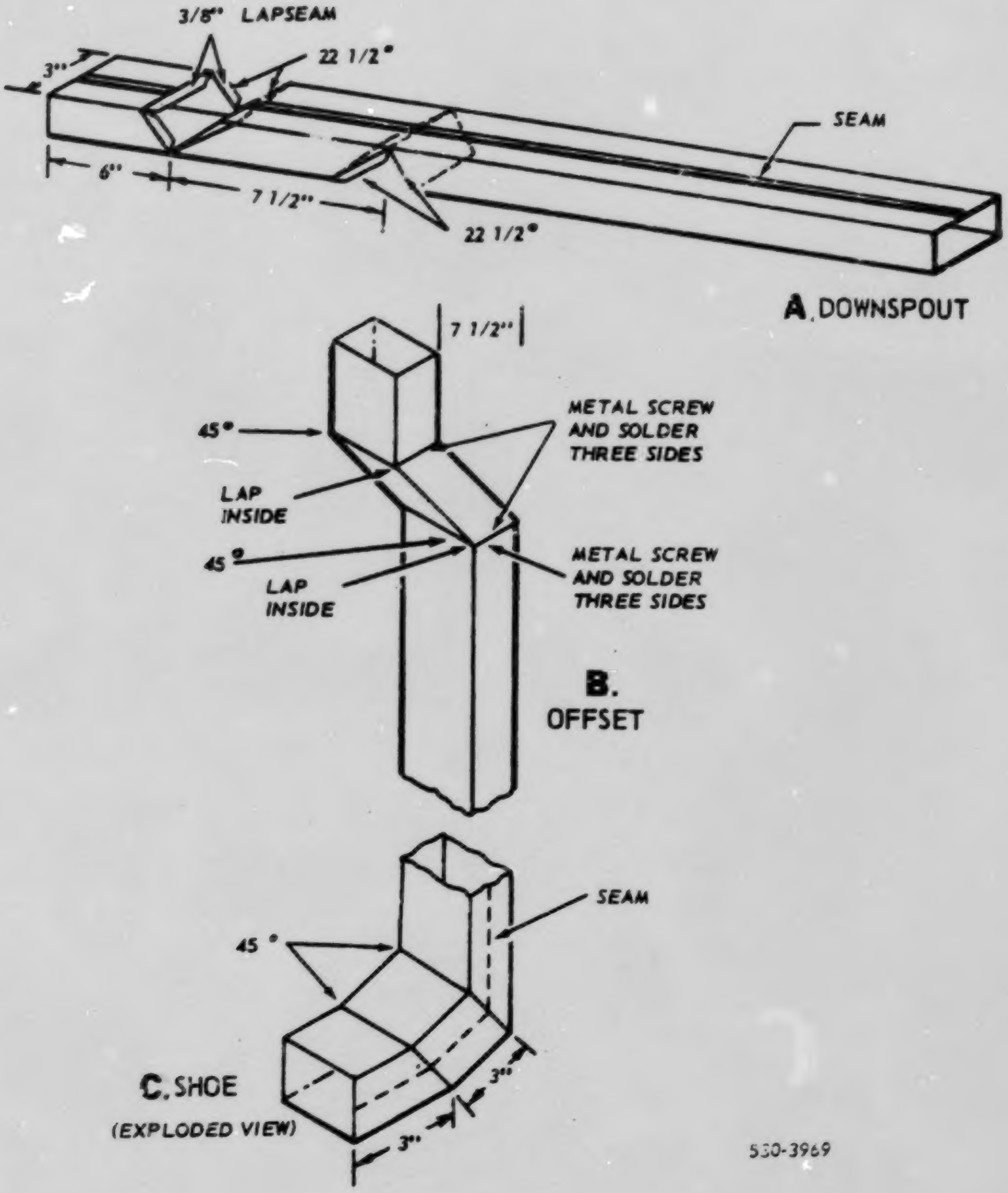
3/8" LAPSEAM
3"
22 1/2°
SEAM
6"
7 1/2"
22 1/2°
A. DOWNSPOUT
7 1/2"
45°
METAL SCREW AND SOLDER THREE SIDES
LAP INSIDE
45°
LAP INSIDE
METAL SCREW AND SOLDER THREE SIDES
B. OFFSET
SEAM
45°
C. SHOE (EXPLODED VIEW)
3"
3"
530-3969

Figure 146. Making downspouts offset and shoe.

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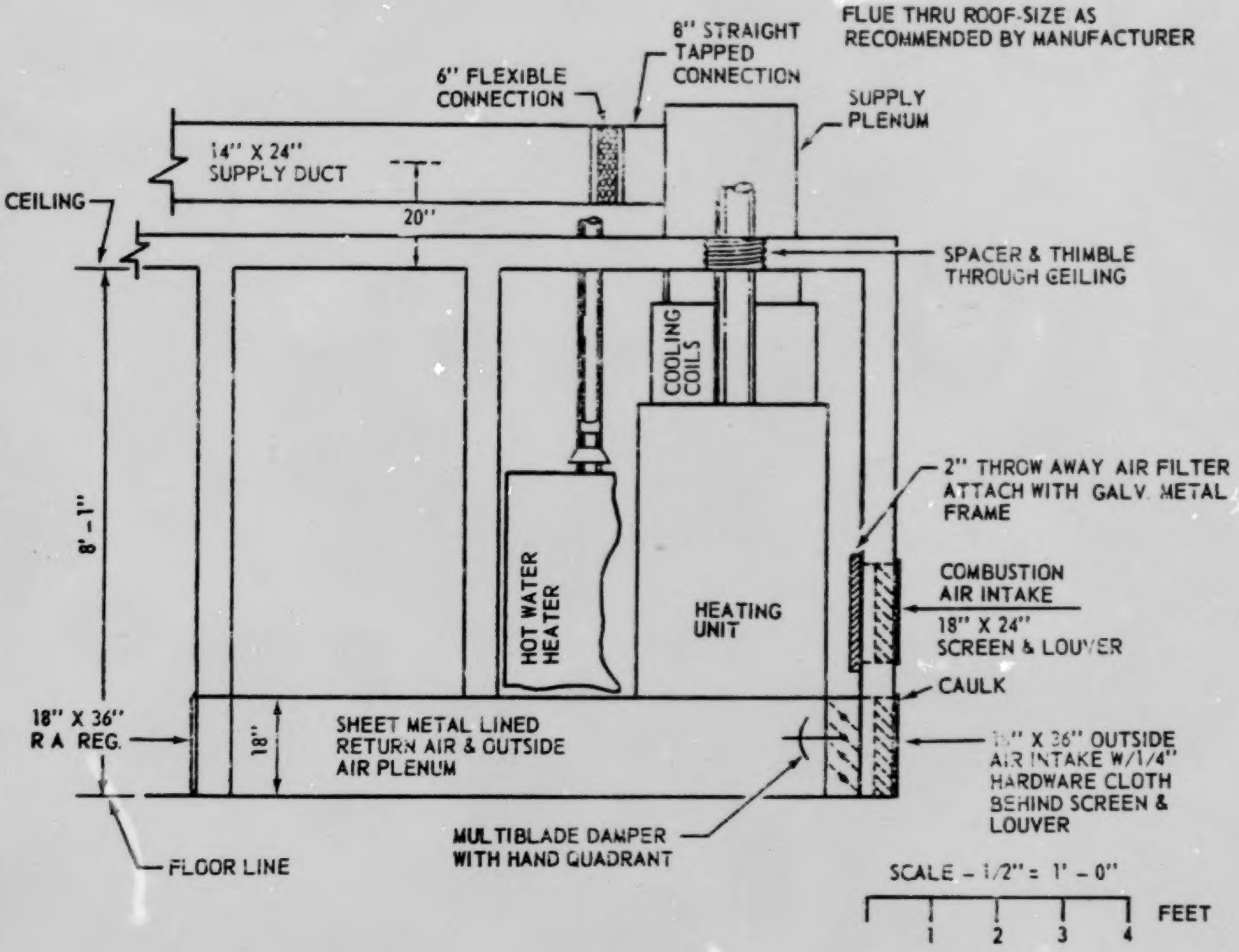
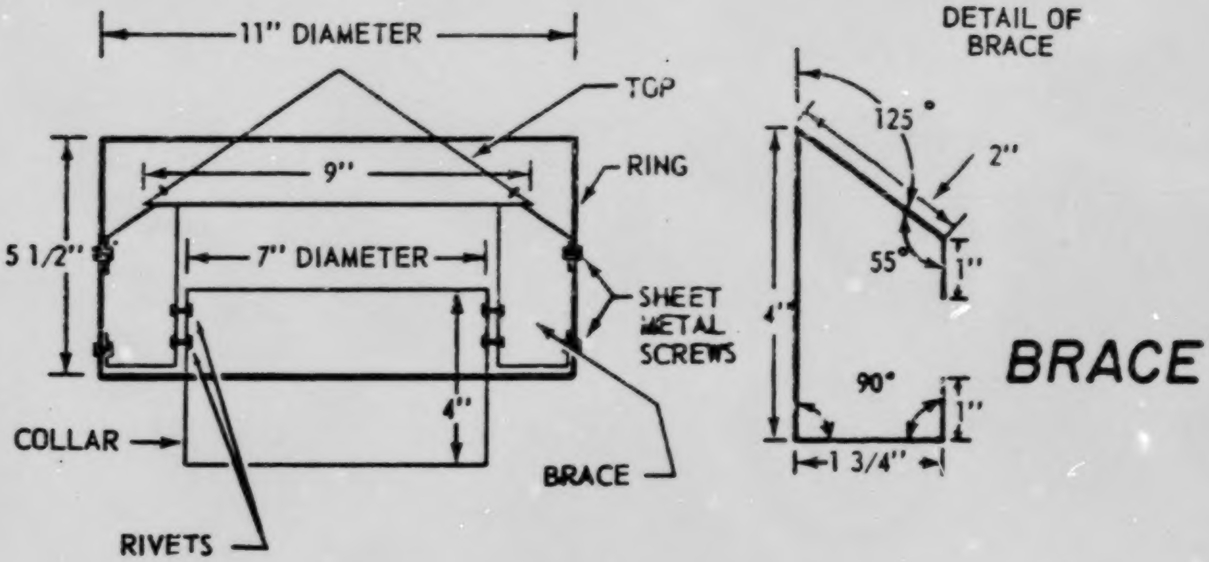
AUGAFB, ALA (743822) 1100

SECTION A-A THRU HEATER ROOM


FLUE THRU ROOF-SIZE AS
RECOMMENDED BY MANUFACTURER
8'' STRAIGHT
TAPPED
CONNECTION
6'' FLEXIBLE
CONNECTION
SUPPLY
PLENUM
14'' X 24''
SUPPLY DUCT
CEILING
20''
SPACER & THIMBLE
THROUGH CEILING
COOLING
COILS
2'' THROW AWAY AIR FILTER
ATTACH WITH GALV. METAL
FRAME
8'-1''
COMBUSTION
AIR INTAKE
18'' X 24''
SCREEN & LOUVER
HOT WATER
HEATER
HEATING
UNIT
CAULK
18'' X 36''
R A REG.
18''
SHEET METAL LINED
RETURN AIR & OUTSIDE
AIR PLENUM
18'' X 36'' OUTSIDE
AIR INTAKE W/1/4''
HARDWARE CLOTH
BEHIND SCREEN &
LOUVER
MULTIBLADE DAMPER
WITH HAND QUADRANT
FLOOR LINE
SCALE - 1/2'' = 1' - 0''
1
2
3
4
FEET

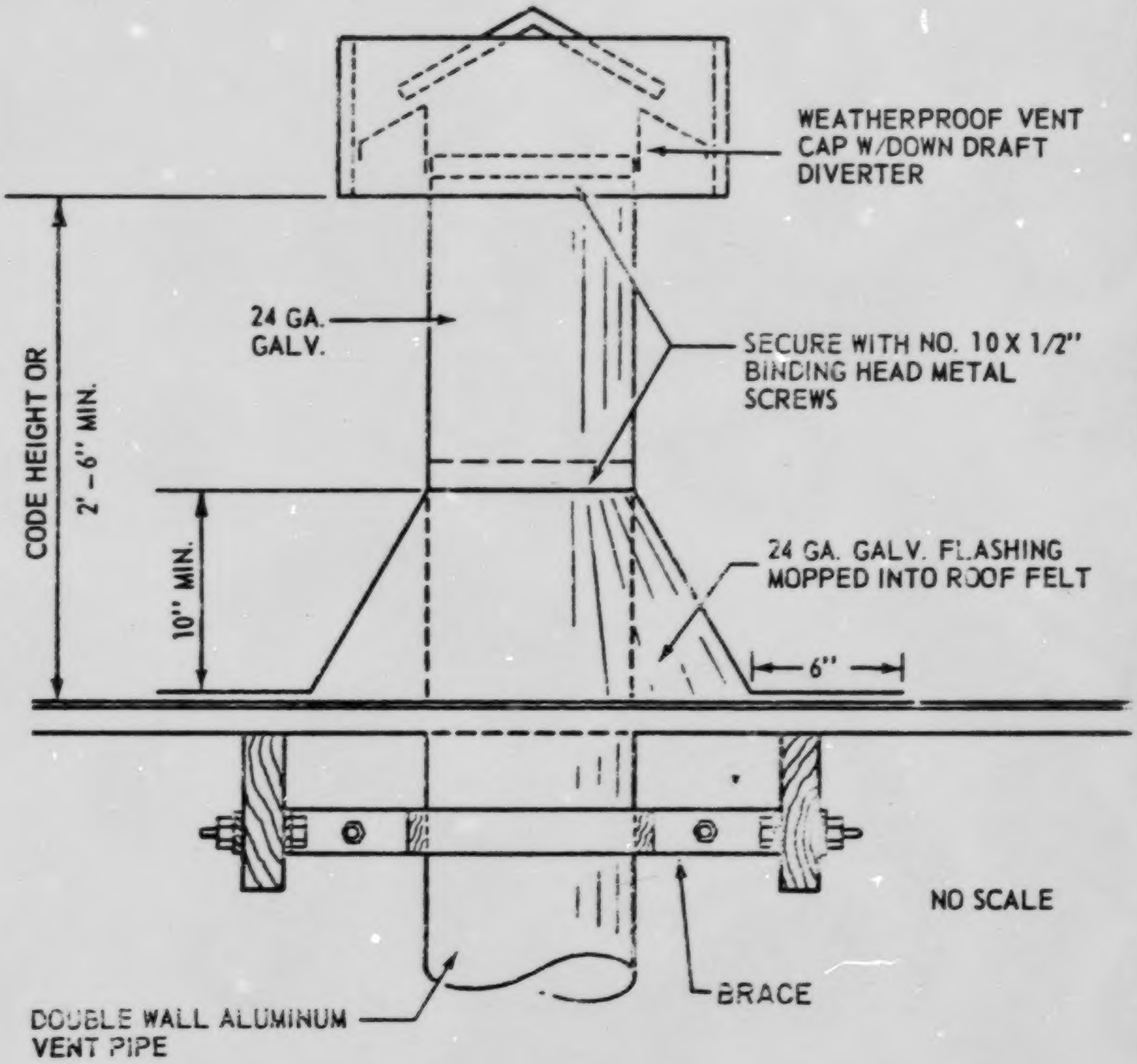
DETAIL OF VENT CAP

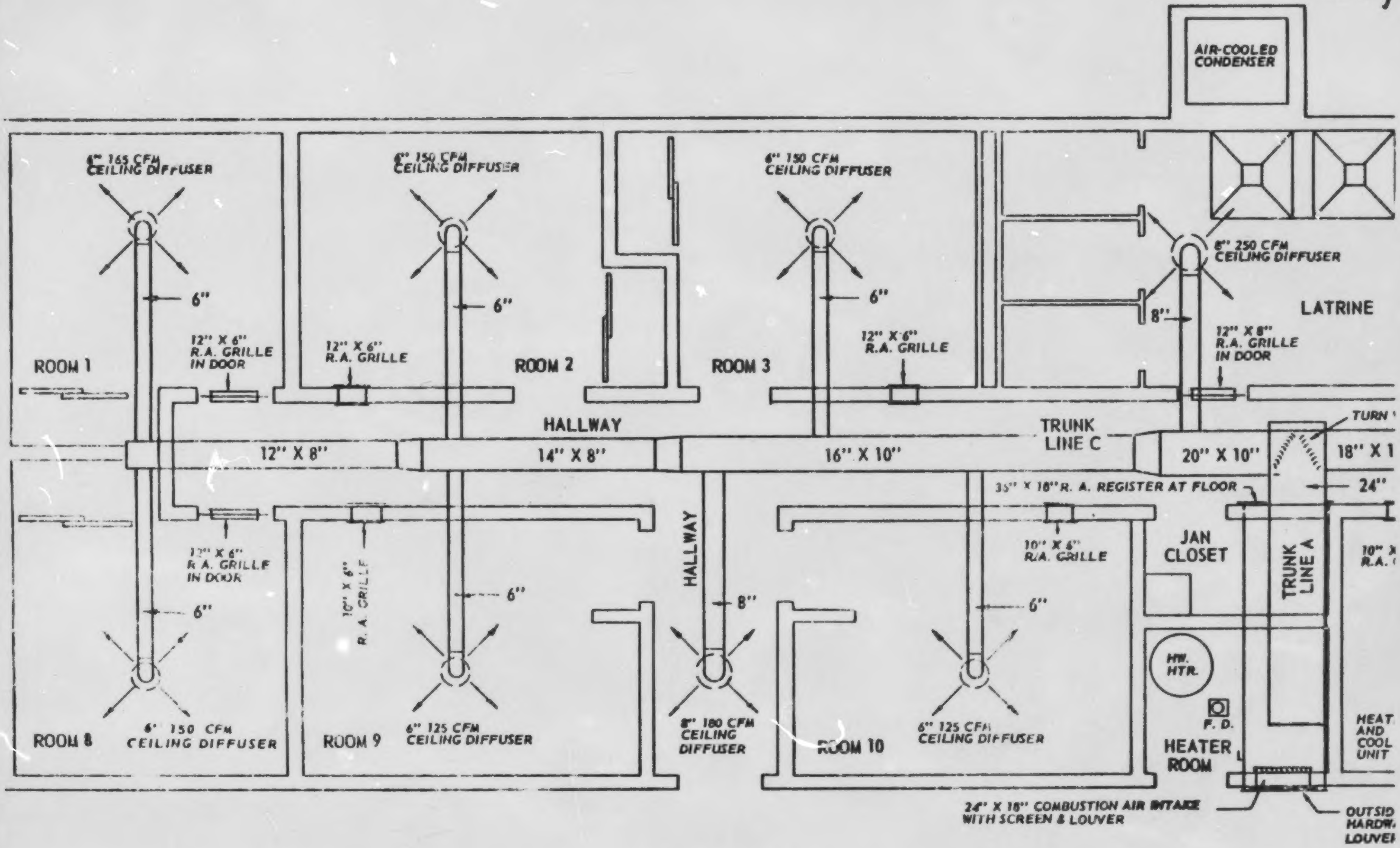

11" DIAMETER
TOP
9"
RING
5 1/2"
7" DIAMETER
SHEET METAL SCREWS
4"
COLLAR
BRACE
RIVETS
DETAIL OF BRACE
125°
2"
55°
1"
4"
90°
1"
1 3/4"
BRACE

NO SCALE

Foldout 2. Elevation views of heater room and flue assembly.

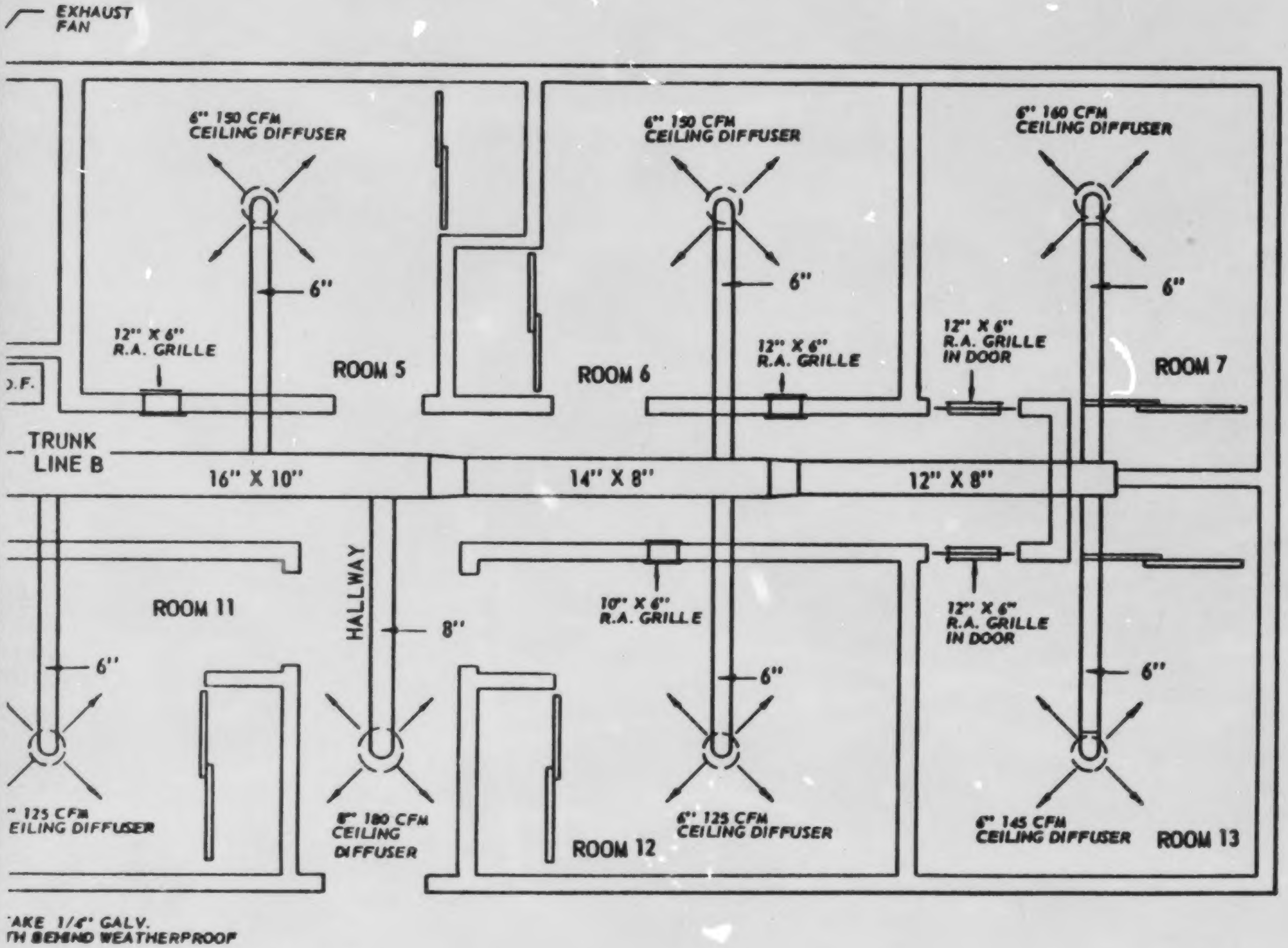
DETAIL OF TYPE B FLUE FLASHING


WEATHERPROOF VENT CAP W/DOWN DRAFT DIVERTER
24 GA. GALV.
SECURE WITH NO. 10 X 1/2" BINDING HEAD METAL SCREWS
CODE HEIGHT OR 2'-6" MIN.
10" MIN.
24 GA. GALV. FLASHING MOPPED INTO ROOF FELT
6"
NO SCALE
BRACE
DOUBLE WALL ALUMINUM VENT PIPE


AIR-COOLED CONDENSER
6" 165 CFM CEILING DIFFUSER
6" 150 CFM CEILING DIFFUSER
6" 150 CFM CEILING DIFFUSER
8" 250 CFM CEILING DIFFUSER
LATRINE
6"
6"
6"
8"
12" X 6" R.A. GRILLE IN DOOR
12" X 6" R.A. GRILLE
12" X 6" R.A. GRILLE
12" X 8" R.A. GRILLE IN DOOR
ROOM 1
ROOM 2
ROOM 3
HALLWAY
TRUNK LINE C
TURN
12" X 8"
14" X 8"
16" X 10"
20" X 10"
18" X 1
24"
35" X 18" R. A. REGISTER AT FLOOR
12" X 6" R.A. GRILLE IN DOOR
10" X 6" R. A. GRILLE
HALLWAY
8"
6"
6"
6"
10" X 6" R/A. GRILLE
JAN CLOSET
TRUNK LINE A
10" X
R.A.
HW. HTR.
F. D.
HEATER ROOM
HEAT AND COOL UNIT
6" 150 CFM CEILING DIFFUSER
6" 125 CFM CEILING DIFFUSER
8" 180 CFM CEILING DIFFUSER
6" 125 CFM CEILING DIFFUSER
ROOM 8
ROOM 9
ROOM 10
24" X 18" COMBUSTION AIR INTAKE WITH SCREEN & LOUVER
OUTSID HARDW. LOUVEI

Foldout 1. Heating and air-

Foldout 1 (continued)


EXHAUST FAN
6" 150 CFM CEILING DIFFUSER
6"
12" X 6" R.A. GRILLE
ROOM 5
6" 150 CFM CEILING DIFFUSER
6"
12" X 6" R.A. GRILLE
ROOM 6
6" 160 CFM CEILING DIFFUSER
6"
12" X 6" R.A. GRILLE IN DOOR
ROOM 7
.F.
TRUNK LINE B
16" X 10"
14" X 8"
12" X 8"
ROOM 11
HALLWAY
8"
10" X 6" R.A. GRILLE
12" X 6" R.A. GRILLE IN DOOR
6"
6"
6"
" 125 CFM
EILING DIFFUSER
8" 180 CFM CEILING DIFFUSER
ROOM 12
6" 125 CFM CEILING DIFFUSER
6" 145 CFM CEILING DIFFUSER
ROOM 13
AKE 1/4" GALV.
TH BEHIND WEATHERPROOF

g floor plan.

NOTE:

1. ALL DUCT WORK TO BE RUN ABOVE CEILING
2. INSULATE WITH ONE LAYER OF 1" FOIL BACKED GLASS FIBER INSULATION
3. ALL CEILING DIFFUSERS HAVE VOLUME DAMPERS
4. ALL RETURN AIR GRILLES ARE TO BE INSTALLED NEAR THE FLOOR

SCALE – 1/4"= 1'0"

1 2 3 4 FEET

391

53350 03 21

WORKBOOK

Fabrication, Installing, and Repairing Sheet Metal Components

SELF-TEACHING AIDS
CRE
VRE
SRG

This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

13-1

EXTENSION COURSE INSTITUTE

Air University

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Chapter Review Exercises
Answers to Chapter Review Exercises
Volume Review Exercise
ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 300 through 322*
300	Making Lap Seams; Making Lock Seams, pages 1-11
301	Joint Connectors, pages 11-22
302	Characteristics and Control of Airflow Through Duct Systems, pages 23-25
303	Duct System Components for Control of Airflow: Splitters; Turn Vanes; Volume Dampers, pages 25-30
304	Duct System Components for Control of Airflow: Ceiling Diffusers; Registers; Grilles, pages 30-33
305	Planning a Duct System: Preliminary Planning; Selecting Sheet Metal, pages 34-37
306	Planning a Duct System: Size and Quantity of Sheets, pages 37-47
307	Planning a Duct System: Selecting Registers, Grilles, Diffusers, Louvers, Dampers, and Insulation, pages 47-49
308	Layout and Fabrication of Duct System Components: Pattern Layout, pages 49-55
309	Layout and Fabrication of Duct System Components: Cutting and Notching, pages 55-58
310	Layout and Fabrication of Duct System Components: Forming and Assembly, pages 58-62
311	Installation of Duct System Components, pages 62-66
312	Repair of Duct System Components, pages 66-69
313	Effect of Wind on Stacks and Ventilators; Stacks and Associated Components, pages 70-76
314	Repair, Fabrication, and Installation of Stacks and Associated Components, pages 76-83
315	Repair, Fabrication, and Installation of Ventilators, pages 83-87
316	Fabrication, Installation, and Repair of Fixed Utility Equipment: Hoods, pages 88-95
317	Fabrication, Installation, and Repair of Fixed Utility Equipment: Serving Line Equipment, pages 96-104
318	Fabrication, Installation, and Repair of Fixed Utility Equipment: Shower Stalls; Fireproof Partitions and Doors, pages 104-110
319	Fabrication, Installation, and Repair of Fixed Utility Equipment: Awnings; Canopies, pages 110-115
320	Fabrication, Installation, and Repair of Metal Roofing, pages 116-129
321	Fabrication, Installation, and Repair of Flashing, pages 129-134
322	Fabrication, Installation and Repair of Gutters and Downspouts, pages 134-148

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

Note for Mandatory CDC Students:

The job training standard knowledge elements specified as minimum requirements for attainment of the 3 level are contained in volume X or CDC 10000 and in this course. If you are a 3-level trainee, as you finish each chapter complete the chapter review exercises that are preceded by an asterisk (*). When you complete the course (or those parts specified for your study), prepare for the SKT by reviewing all the text subject areas that contain the answers to the asterisked exercises. If you are a 5-level trainee, complete all chapter review exercises.

The illustrations referenced in these review exercises and answers are located in the text and in this workbook. Illustrations located in the text are identified and referenced as figure 1, figure 2, etc. Illustrations located in the workbook are identified and referenced as figure CRE–1, figure CRE–2, etc. and as figure CRE Ans–1, figure CRE-Ans–2, etc.

CHAPTER 1

Section 1

Objectives: Given data for lap seams, solve problems, determine pattern dimensions, determine number and location of rivet holes, and describe tools needed for fabricating lap seams.

*1. If 24-gage sheet metal is used to make a flat lap seam, as illustrated in figure 1, what will be the seam allowance? (1-5; Figs. 1, 6)

2. You are to make a round pipe 4 inches in diameter and 36 inches long from 16-gage sheet metal. A riveted flat lap seam will be used.

   a. What will be the total width of the stretchout including the seam allowance? (1-6; Figs. 1, 6)

   b. How far from the edge will the centerline for the rivet holes be located? (1-6; Fig. 1)

   c. What will be the distance between the centers of the rivet holes, and what will be the distance from the center of each end hole to the end of the pipe? (1-6)

   d. What will be the total number of holes to be located? (1-6)

Section 2

Objectives: Given sheet metal fabrication data requiring lock seams (such as standing seams, grooved seams, double seams, Pittsburg lock seams, and dovetail seams), determine seal allowance, explain how lock seams are made, and solve problems concerning fabrication of lock seams.

*1. What type of seam can be used as bracing to reduce vibration in a long joint of rectangular duct? (2-2)

2. When making a standing seam in 24-gage sheet metal, what will be the seam allowance for the folded side if the 90° flanged side is 1 inch in height? (2-3; Fig. 18)

*3. In step B of figure 8, is the $2\frac{11}{16}$-inch measurement on the vertical or on the horizontal leg of the 90° angle if the piece of 24-gage sheet metal is being bent on the $2\frac{11}{16}$-inch seam allowance line? (2-4; Fig. 8)

*4. Why is more thickness allowance made for grooved seams than for standing seams? (2-5; Fig. 11)

5. What will be the total allowance for a ½-inch grooved seam to be made from 24-gage (0.025-inch) sheet metal if a bar folder and hand groover are used? (2-6; Fig. 18)

6. In which direction should the edges be turned on two or more sheets of metal that are to be joined with grooved seams? Why? (2-9)

*7. If you are fabricating round and square ducts, which seams would be best suited if you have a Pittsburg lock forming machine in the shop? (2-11, 20)

8. How much seam allowance should be made on 20-gage (0.037-inch) sheet metal if a ½-inch grooved seam is to be made with a Pittsburg lock forming machine? (2-11; Fig. 18)

*9. You are using 20-gage sheet metal to make pieces 1 and 2 for a standing seam to be formed into a grooved seam, such as that illustrated in figure 13. What should be the height of the flange of piece 1 if the channel for piece 2 is ⅜ inch deep? Why? (2-14; Figs. 13, 18)

10. What mistake was made in the fabrication of a 24-gage grooved seam from a ½-inch standing seam if piece 2 with the 180° fold is ⅛ inch too short? (2-14, 3; Fig. 18)

*11. What is the allowance to the nearest $\frac{1}{16}$ inch for a ⅜-inch corner double seam that is to be made in 20-gage sheet metal? (2-16; Fig. 18)

12. A 20-gage duct joint to be fabricated will be 12 inches high, 18 inches wide, and 30 inches long. One corner is to be connected with a ½-inch corner double seam. The 12-inch side will be flanged, and the 18-inch side will be turned 180°. What will be the length, including seam allowance, of each side that meets at the corner double seam? (2-16; Fig. 18)

13. When a bar folder is used, how can step A in figure 10 be modified to bend the 90° flanged edge of a ¼-inch corner double seam? How can step B be modified to bend the folded edge? (2-17; Fig. 10)

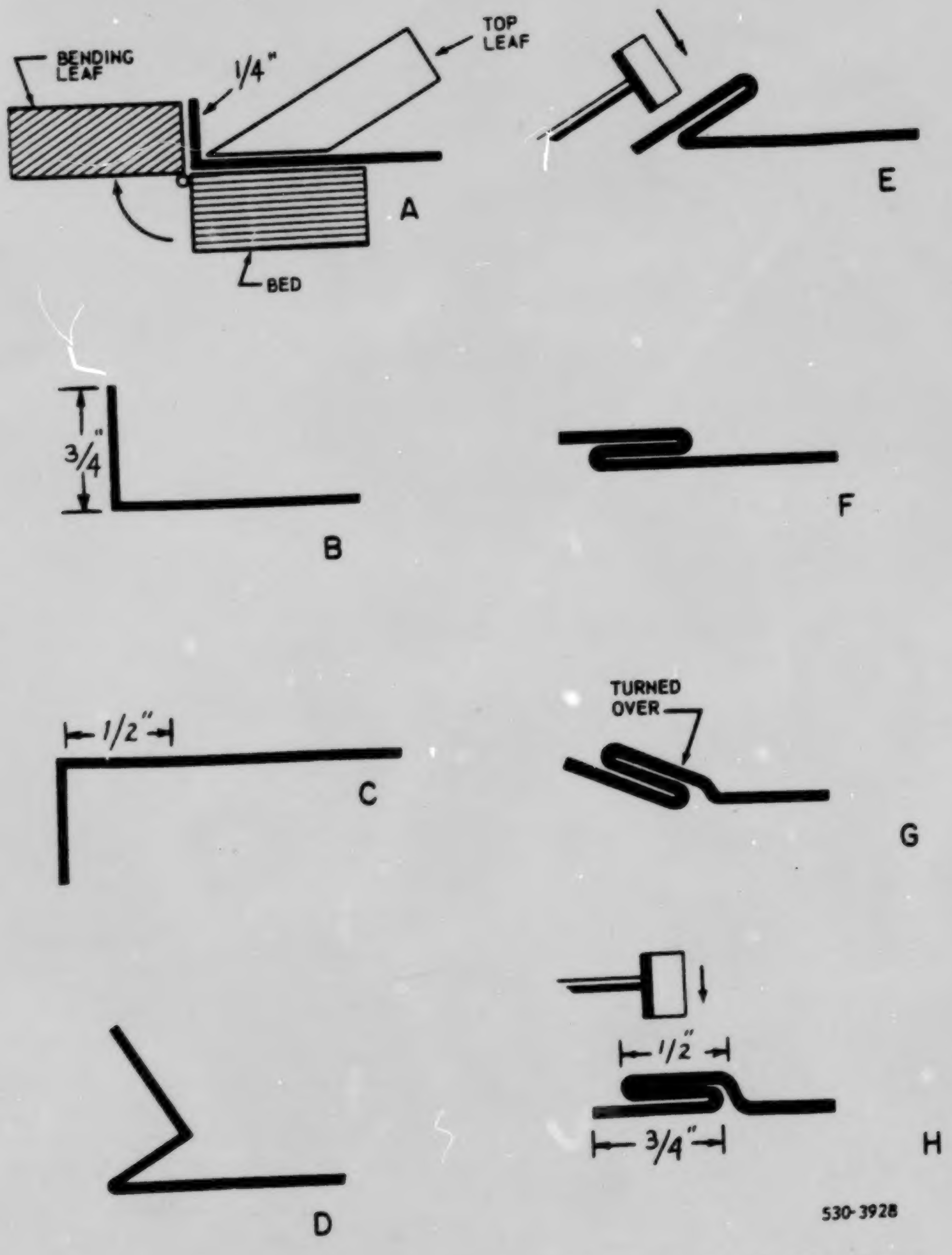
BENDING LEAF
1/4"
TOP LEAF
A
BED
E
3/4"
B
F
1/2"
C
TURNED OVER
G
D
1/2"
3/4"
H
530-3928

Figure CRE-1. Making a Pittsburg lock seam with a cornice brake and mallet (problem).

*14. Fill in the blanks. Several tools are needed to make a ¼-inch bottom double seam, like the one illustrated in figure 15, on a 12-inch diameter cylinder. A ____________ machine is used to turn the 90° flange on the bottom disc, which is ____________ inches in diameter. A ____________ machine is used to turn the 90° flange to a height of ____________ inch at the bottom of the cylinder. A ____________ hammer or ____________ is used to turn the bottom edge ____________ inch over the flange at the bottom of the cylinder. A ____________ machine is used to tighten the 180° fold over the 90° flange. The bottom double seam is completed as shown in step E of figure 15 by using a mallet and a ____________. (2-19; Fig. 15)

*15. Fill in the blanks. A Pittsburg lock forming machine will be used to make a Pittsburg lock seam in 20-gage sheet metal. Previously the machine was used with 24-gage sheet metal. The ____________ should be set for 20-gage (0.037-inch) sheet metal. The allowance needed to make the pocket side of the seam will be ____________, ____________, or ____________ inches, depending on the make and model of the machine. After power is turned on, the metal is placed ____________ against the guide and fed into the rollers. When the metal comes out of the machine, it will look like view ____________ in figure 16. The 90° flange shown in view ____________ is made with a cornice brake or ____________. The final step of assembly of a Pittsburg lock seam is to turn down the locking edge on the pocket side and ____________ the seam as shown in view C of figure 16. (2-20, 21, 24; Fig. 16)

16. This exercise involves the steps required to make a Pittsburg lock seam with a cornice brake and mallet. Step A in figure CRE-1 shows how the ¼-inch flange is made. Steps B through H illustrate how the pocket side of the seam is made. In steps B through H, draw (add) the correct positions of the following: sheet metal, bending leaf, topleaf, and bed. When you have added these to figure CRE-1, it should somewhat resemble figure 8. (2-34; Figs. 8, CRE-1)

*17. Why should you use a dovetail seam instead of an outside lap seam (outside flange) to secure a flat base to a cylinder? (2-25, 19; Fig. 16)

18. If you were to make another dovetail seam on the other end of A or B in figure 17 so that either one could be fastened to form a T-joint, how far should the tabs be cut to make a ½-inch seam? (2-26; Fig. 17)

Section 3

Objectives: Given sheet metal fabriction and assembly data requiring joint connectors (such as standing seams, S-slips, drive slips, tapped connections, and takeoff fittings), determine kind to use, material required, and metal allowances; develop patterns; and solve problems concerning fabrication and assembly of joint connectors.

*1. What joint connector is also used as a seam for connecting pieces of sheet metal? (3-3; 2-2)

2. What is the length of piece 1 and piece 2 illustrated in figure 20? The 5-foot rectangular duct joint is constructed of 24-gage (0.025-inch) sheet metal and stiff-

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ened with a 1-inch standing seam across the center. (3-4, 2-3; Figs. 18, 20)

*3. If a flat S-slip allows an overlap of 1 inch, why will the allowance be only ½ inch for the additions to each sheet being joined? (3-6; Fig. 21)

*4. Which S-slip illustrated in figure 22 is best suited for connecting duct sections that are made of 24-gage sheet metal and measure 10 inches high, 20 inches wide, and 36 inches long? (3-8; Figs. 22, 28)

5. How much material is required to form a 13¾-inch standing S-slip with a 1⅛-inch pocket and a 1¼-inch standing edge? (3-9; Fig. 23)

6. What is the likely mistake in the forming of a standing S-slip, as illustrated in figure 23, if the last 180° bend measures 1⅛ inches? (3-9; Fig. 23)

7. What are the dimensions of a pattern for a reinforced standing S-slip for a joint that is 22 inches wide? (3-11, 9; Fig. 23)

8. What will be the dimensions of a drive slip which is incorrectly made because the depth gage bar of the bar folder is set at 9/16 inch instead of ½ inch for the 180° bends? (3-15; Fig. 26)

*9. What is probably wrong if a drive slip will not slide into the folded edges of two duct joints as shown in step C of figure 27? The turned back edges of the duct joints have been made correctly. (3-18; Fig. 27)

*10. Use figure 28 and determine what type of S-slip is recommended to connect 12-inch by 24-inch galvanized sheet iron duct joints that are each 36 inches long. (3-22; Fig. 28)

11. A rectangular duct 16 inches by 30 inches is to be made in joints 5 feet 8 inches long and connected with standing S-slips and drive slips. Job specifications require maximum strength to be incorporated. In addition to using reinforced standing S-slips at each end, what are three additional ways the duct can be strengthened? (3-22; Fig. 28)

*12. What is the allowance for a tapped connection that has a 1-inch flange (frame) and 1-inch tabs? (3-24; Fig. 29)

13. A throat and heel pattern, such as that illustrated in figure 29, is to have a ¾-inch flange and ¾-inch tabs. The takeoff fitting will be connected to a branch line with 1⅛-inch S-slips and drive slips.
    a. If the throat pattern is 7 inches long, what will be its total length including allowances?
    b. If the heel pattern is 13¼ inches long, what will be its total length including allowances?
    (3-24, 16, 6; Fig. 29)

*14. Notches and slits are shown on pattern A and pattern B of figure 32.
    a. How many 45° notches are shown for the S-and-drive connection allowance?
    b. How many 45° notches are shown for the Pittsburg lock seam allowance? How many 90° notches?
    c. How many slits are shown for the tapped connection allowance?
    d. How many slits are shown for the Pittsburg lock seam allowance?
    (3-30; Fig. 32)

15. Draw and label the allowances (as in fig. 32) for the top pattern piece 1 in figure CRE–2 showing the dimensions of the allowances.
    a. Draw the cross brake lines and include instructions.
    b. Draw the allowances for 1-inch Pittsburg lock seam pockets on both sides of the top pattern.
    c. Draw the allowances needed for a tapped connection which has a ¾-inch flange and ¾-inch tabs.
    d. Draw the allowances for an S-slip connection.
    (3-30, 29; Figs. 32, CRE–2)

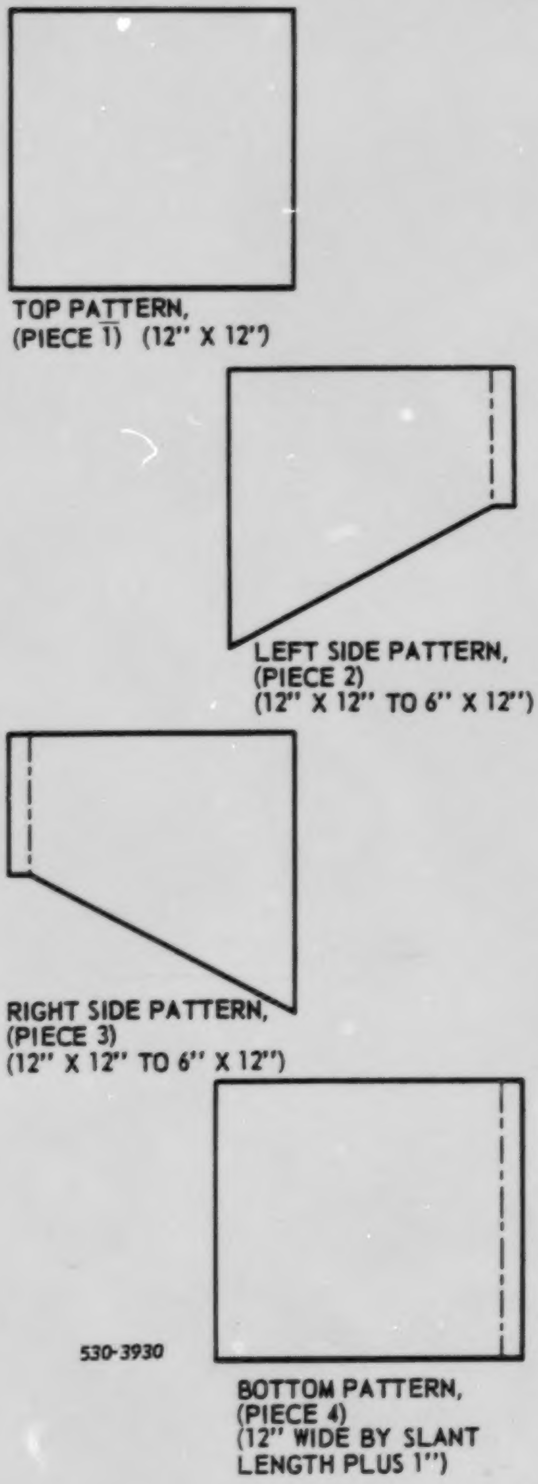
TOP PATTERN,
(PIECE 1) (12" X 12")
LEFT SIDE PATTERN,
(PIECE 2)
(12" X 12" TO 6" X 12")
RIGHT SIDE PATTERN,
(PIECE 3)
(12" X 12" TO 6" X 12")
530-3930
BOTTOM PATTERN,
(PIECE 4)
(12" WIDE BY SLANT LENGTH PLUS 1")

Figure CRE–2. Patterns for a takeoff fitting.

16. Draw and label the allowances for the left side pattern (piece 2) in figure CRE–2. showing the dimensions of the allowances.
    a. Draw the cross brake lines and include instructions.
    b. Draw the allowances on both sides of the pattern for the ¼-inch flange of the Pittsburg lock seam.
    c. Draw the allowances needed for a tapped connection which has a ¾-inch flange and ¾-inch tabs.
    d. Draw the allowance for the drive slip connection.
    (3-30. 29; Fig. CRE–2)

17. Draw and label the allowances for the right side pattern (piece 3) in figure CRE–2 showing the dimensions of the allowances.
    a. Draw the cross brake lines and include instructions.
    b. Draw the allowances on both sides of the pattern for the ¼-inch flange of the Pittsburg lock seam.
    c. Draw the allowances needed for a tapped connection which has a ¾-inch flange and ¾-inch tabs.
    d. Draw the allowance for the drive slip connection.
    (3-30. 29; Fig CRE–2)

18. Draw and label the allowances for the bottom pattern (piece 4) in figure CRE–2. showing the dimensions of the allowances.
    a. Draw the cross brake lines and include instructions.
    b. Draw the allowance for a 1-inch Pittsburg lock seam pocket on both sides of the pattern.
    c. Draw the allowance needed for a tapped connection which has a ¾-inch flange and ¾-inch tabs.
    d. Draw the allowance for an S-slip connection.
    (3-30. 29: CRE–2)

*19. In the bottom pattern of figure CRE–2. should the tapped connection flange be formed first or should the Pittsburg lock seam pockets be formed first? (3-31. 37; Fig. CRE–2)

20. Figure 32 shows the inside surfaces of a takeoff fitting. Will the inside or outside surface be facing *up* when the cross brake bends are made with a cornice brake? (3-32; Fig. 32)

21. The bottom pattern in figure 32 will have the tapped connection flange bent down (to the outside). Should the pattern be run through the Pittsburg lock forming machine with the inside face up as illustrated or should the pattern be turned over? Why? (3-37; 2-24; Fig. 32)

*22. Why does the last sentence in paragraph 3-37 say the fourth step is not necessary? (3-37, 31; Fig. 32)

CHAPTER 2

Section 4

Objectives: Given duct system data requiring straight duct and elbows. use rules of good duct design to determine what type of straight duct will deliver the most air and the best elbow dimensions that will allow maximum airflow.

1. Which of the following 50-foot straight ducts will deliver more air from a blower: One with dimensions that are 20″ x 30″ or one with dimensions that are 15″ x 35″? Why? (4-4. 5)

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*2. What rule of duct design applies to the maximum angles for the transitions of a diverging and converging duct such as that illustrated in figure 37? (4-4, 7; Fig. 37)

*3. What shape of straight duct has the best airflow characteristics? (4-5)

4. A duct is to have an enlargement to accommodate a heating coil twice as large as the duct. Will the diverging or the converging transition require splitters if each is at 15° angles to the duct? (4-7; Fig. 37)

*5. What will be the inside radius ratio of elbow A in figure 38 if the dimensions are changed to 8 inches high, 20 inches wide, and a 10-inch throat radius? (4-10; Fig. 38)

6. If a drawing does not require splitters in an elbow, what throat radius would be best suited for maximum airflow in an elbow that is 8 inches wide? (4-10; Fig. 38)

*7. Instead of using a splitter in elbow A shown in figure 39, what bend radius could be used to raise the inside radius ratio to 1? (4-10; Fig. 39)

Section 5

Objectives: Given duct system data concerning airflow control components (such as splitters, turn vanes, diffusers, registers, and grilles), interpret working drawings, explain installation procedures, solve problems, and determine dimensions that will allow maximum airflow.

1. What would be the inside radius ratio of each passage if the splitter in elbow A of figure 39 is placed through the center of the elbow? (5-3; Fig. 39)

*2. If the radius of each turn vane shown in figure 41 is 4½ inches, what will be the width of the stretchout for each turn vane? This distance includes the length of the 90° bend plus the two straight edges. (5-8, 9; Fig. 41)

3. You are to fabricate turn vanes for a rectangular elbow (similar to the one shown in fig. 41) that measures 14 inches by 14 inches. The turn vanes are to be 3 inches apart and secured with ¾-inch tabs.
   - *a.* What are the dimensions to the nearest ¼ inch for the stretchout of each turn vane (including allowances)? (5-8, 9; Fig. 43)
   - *b.* How many turn vanes will be needed? (5-8; Fig. 43)
   - *c.* How many tabs will be used on each turn vane? (5-10)

*4. In the plan view of figure 43, what type of damper should be installed at the branch line entrance if adequate airflow is *not* being distributed to the branch line? (5-12; Fig. 43)

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5. What is the approximate size of the deflecting damper shown in figure 42 if the trunk line is 16 inches wide and 10 inches high? (5-13; Fig. 42)

*6. What would be wrong with the butterfly damper shown in figures 43 and 44 if the blade is in the horizontal position as shown, but the quadrant handle is at a 45° angle to the left of straight down? Why? (5-16; Figs. 43, 44)

7. During fabrication of a duct, you are to install a butterfly damper in a duct joint that is 16 inches wide, 12 inches high, and 36 inches long.
   a. What are the dimensions of the damper blade? (5-15)
   b. Which end of the damper blade should have the attachment plate with the square shaft? (5-16; Fig. 46)
   c. How do you determine if the square shaft is inserted in the control quadrant correctly or with a 90° error? (5-16; Fig. 44)
   d. What is wrong if the damper blade shown in figure 44 strikes the bottom of the duct and will not close? (5-16; Fig. 44)

*8. Foldout 2 is a working drawing of a heater room and flue assembly. Where does this drawing indicate the location of a louver damper? How is the louver damper operated? (5-19; FO 2)

9. If the blades of a louver damper, such as that shown in figure 47, remain in the open position when the motor is not operating, what are two possible causes and their remedies? (5-21; Fig. 47)

*10. When installing a volume damper assembly, such as that shown in figure 48, will the heads of the sheet metal screws be visible on the inside of the flange or on the outside of the duct? Why? (5-23; Fig. 48)

11. What mistake was made in the mounting of a ceiling diffuser and volume damper if the duct outlet is flush with the ceiling but the frame of the damper assembly is ¼ inch from the ceiling on one side? (5-23; Fig. 48)

*12. What should be the dimensions of a register blade frame that is to be installed at the supply outlet of a 14 x 16-inch branch line? (5-26)

13. You are to install a multiple blade register like the one shown in figure 49. This includes drilling or punching holes for the number 8 countersunk oval-head sheet metal screws in the ¾-inch flange of the duct. What procedure should you use to insure that the holes are marked properly so that the holes can be made in the correct places? (5-26; Fig. 49)

*14. How many return air door grilles and wall grilles would you have to install for the duct installation in foldout 1 of the text? In what rooms are the door grilles located? What rooms have wall grilles? (5-27; FO 1)

15. In foldout 1 why is the latrine door return air grille 12 x 8 inches if the other return air grillles are only 12 x 6 inches? (5-27; FO 1)

CHAPTER 3

Section 6

Objectives: Given duct system data, interpret working drawings and patterns; perform preliminary planning concerning duct components, seams, connections, stiffeners, and pattern dimensions; and determine what materials to use, including kind, gage, size, and quantity.

*1. In foldout 1 the dimensions for the rectangular duct of trunk line A are listed as 24" x 14". What are two ways to determine which dimension is the width? (6-5; FO 1; and Vol. 1)

2. Use foldout 1 and break trunk line C down into sizes, using procedures similar to these explained for the breakdown of trunk line B. The total length of the subdivisions should equal the total length of trunk line C (42 feet). (6-7, 6; FO 1)

*3. Why does each branch line in rooms 3, 2, and 1 increase only 1 inch in length when the width of the trunk line sections decreases from 16 inches to 14 inches to 12 inches? (6-9; FO 1)

4. If the duct sections in trunk line B were changed to 20" x 10", 18" x 10", 16" x 8", and 14" x 8", what would be the length of the branch lines in rooms 5, 12, and 7? (6-9; FO 1)

*5. Why are grooved seams rather than Pittsburg lock seams used in the branch line joints of foldout 1? (6-15, 16; 2-5; FO 1)

6. In the blanks in Column 1, fill in the numbers from Column 2 that match the type of seams that should be used in the duct system shown in foldout 1.

Column 1

— *a.* Used to connect the branch lines to the trunk lines ____. (6-19; 2-26; Fig. 17; FO 1)
— *b.* Used to install ends in trunk lines A, B, and C ——. (16-19; 7-9; Fig. 67)
— *c.* Used to install the cover for the plenum ——. (6-19; 7-9; Fig. 67)
— *d.* Used in each branch line joint ______. (6-16; FO 1)
— *e.* Used in each transition ______. (6-17; FO 1)

Column 2

1. Standing seams
2. Grooved seams
3. Dovetail seams
4. Pittsburg lock seams

7. Under what condition is it recommended to use standing S-and-drive slips to connect the 12″ x 8″ joints of trunk lines B and C? (6-20; Figs. 28, 57, 60)

*8. What joint connections, and how many of each, are used in the return air duct (return air and outside air plenum) illustrated in foldout 2 and figure 62? (6-20, 12; Fig. 64; FO 2)

*9. The rectangular duct sections shown in foldout 1 will be made into several joints. How many sides of each joint should be stiffened by cross braking? (6-23; Fig. 28; FO 1)

*10. Why is galvanized sheet iron better suited for the duct in foldout 1 than black iron? (6-25; FO 1)

11. What kind of sheet metal should be selected if the duct job in foldout 1 is to be altered and installed below the ceiling? (6-25; FO 1)

*12. What gage of galvanized sheet iron is recommended for the 12″ x 8″ sections of trunk lines B and C of foldout 1? (6-26; Fig. 28; FO 1)

13. Fill in the blanks. What gages of galvanized sheet iron should be used in the following sections of the duct system in foldout 1?
   a. Trunk line A __________ gage.
   b. Trunk lines B and C
      (1) 20″ x 10″ section __________ gage.
      (2) 16″ x 10″ section __________ gage.
      (3) 14″ x 8″ section __________ gage.
      (4) 12″ x 8″ section __________ gage.

   c. Return air duct __________ gage.
   d. Branch lines __________ gage.
   (6-26; Fig. 28; FO 1)

*14. Why is the 36″ x 97¼″ pattern piece shown in figure 52 cut from a sheet 10 feet long rather than from a sheet 8 feet long? (6-31; Fig. 52)

*15. How many and what size whole sheets are needed for the patterns to make the eight numbered joints of truck line A and the plenum shown in figure 53? (6-31–39; Figs. 53–55)

16. Use figure 55 and answer the following questions.
   a. What are the dimensions of the largest leftover piece in sheet 1, and is it large enough to make a drive slip in trunk line B or C? (Figs. 26, 55; FO 1)
   b. How many standing S-slips for trunk line B can be made from the leftover pieces in the four sheets shown in figure 55? (Figs. 55, 23, FO 1)
   c. How many drive slips for the 18″ x 10″ and 16″ x 10″ sections of trunk line B (FO 1) can be made from the leftover material from the four sheets in figure 55? (Figs. 55, 26; FO 1)

17. Figure 56 shows the flexible connection (joint 3) used in trunk line A. Why are the metal pieces each 77¼ inches long, whereas the asbestos cloth is only 77 inches long? (6-39, 34; Fig. 56)

*18. How many sheets of metal, by sizes, are estimated for layout and fabrication of the rectangular portion of trunk line B? (6-24–47; Figs. 58, 59)

*19. Why is a 4′ x 10′ sheet used for sheet 5 of figure 59? (6-45; Fig. 59)

*20. Figures 58 and 59 (sheet 6) show the amount of metal (including allowances) needed to make transitions 2, 8, and 12. What are the stretchout dimensions (without allowances) for material to make each of the three transitions? (6-46, 37; Figs. 57, 58, 59)

*21. In figure 59, how much leftover material is there in each of the seven sheets? (List the approximate dimensions.) (6-47; Fig. 59)

22. Figure 60 shows a breakdown of trunk line C. You are to make a materials required list similar to that in figure 58 and sketches of each sheet similar to those in figure 59. When you complete this assignment, answer the following questions.
   a. Joint 1 in figure 60 is in the 20″ x 10″ section and is connected to the takeoff fitting at one end and to the first transition at the other. What are the dimensions, including allowances, of the metal needed to make joint 1? (6-48; Fig. 60)
   b. In figure 60, could the 23-inch joint of the 16″ x 10″ section have been located in a different place? (Fig 60)
   c. In figure 60, why are joints 14 and 15 4′8″ centers instead of 35″ centers? (6-48; Fig. 60)
   d. What are the dimensions (including allowances) for each piece needed to make joints 1, 2, 3, and 4? (Fig. 60)
   e. In figure 60, how many whole sheets and what sizes are needed to make joints 1 through 8 with the least amount of waste? (Omit material for S-and-drive slips for this question.) (Fig. 60)
   f. How many standing S-slips and drive slips, listed by sizes, will be required to connect joints 1 through 8 shown in figure 60? (Fig. 60)

*23. In figures 57 and 60 what rooms have round duct joints greater than 12 inches long but less than 34½ inches long? (6-50; Figs. 57, 60)

24. Figures 57 and 60 show the breakdown of the round duct branch lines of trunk lines B and C.
   a. What will the pattern dimensions be for the 34½-inch joints in the 8-inch branch line ducts?
   b. How many joints 34½ inches long and 8 inches in diameter are needed?
   c. How many 3′ x 10′ sheets will be needed to make all of the 34½-inch joints plus the one 25½-inch joint?
   (6-51, 50; Figs. 57, 60)

*25. Figure 61 is an elevation view of a branch line that shows the drop joint in one of the 6-inch branch lines.
   a. What is the length (including the joint connection allowance) of the 6-inch drop joint shown in figure 61?
   b. What is the length (including the joint connection allowance) of the drop joints located in rooms that have 8-inch branch lines? (6-54; Figs. 61, 57, 60)

26. Make a materials required list and sheet sketches (such as figs. 58 and 59) for the branch line illustrated in figure 61. Make the sheet sketches on a 3′ x 8′ sheet showing the pattern pieces arranged with the least amount of leftover material. What are the dimensions of the largest rectangle that can be made from the leftover piece? (6-55, 49–54; Fig. 61)

*27. What different kinds and sizes of adjustable volume dampers, and how many of each, are used in the duct system shown in foldouts 1 and 2? (6-61; FOs 1, 2)

*28. How many and what size pieces of 1-inch foil-backed insulation, 48 inches wide, will be needed to wrap trunk line A shown in figure 53? Insulation for joints 7 and 8 will be included in trunk lines B and C. What will be the size of the two cutouts for joints 7 and 8? (6-63; Fig. 53)

29. What size and how much foil-backed insulation 1-inch thick will be needed to wrap the branch line in room 2 (fig. 60) from the trunk line to the ceiling diffuser? A similar room is shown in figure 61. The insulation for joints 1 through 4 will be 6′11″ x 24″; the drop joint will be 10⅜″ x 24″; and the elbow will be 13½″ x 24″. The insulation for the elbow includes 2 inches at each end for the straight pieces to lap over. (6-63, 9; Figs. 60, 61)

Section 7

Objectives: Given duct system data, explain and resolve questions about how patterns for duct system components are developed, cut, notched, formed, and assembled, develop patterns and determine what tools and equipment are needed.

*1. The following questions are based on figure 63, which is the pattern for joints 4 and 5 of trunk line A.
   a. Why is the pattern developed with the parallel line layout methods? (7-2, 3; Fig. 63; and Vol. 1)
   b. Why are the element lines 35 inches long? (7-4; Figs. 53, 63)
   c. Why are the element lines spaced 14 inches and 24 inches apart? (7-4; Figs. 53, 63)
   d. Why is a sheet 77¼″ x 36″ required to make the pattern? (7-4, 17; Fig. 63)
   e. Why are notches made at the corners and element lines? (7-21; Fig. 63)

*2. The following questions concern joint 1 of trunk line B in figure 57.
   a. What layout method should be used to develop the pattern? (7-3, 4; Fig. 57)
   b. How many element lines will the pattern have? (7-4; Figs. 57, 63)
   c. What are the pattern dimensions, including seam and joint allowances? (7-3, 4; Figs. 57, 63)
   d. How many slides will be cross broken? (7-28; Figs. 57, 63)

3. Joint 15 of trunk line C (fig. 60) is in the 12″ x 8″ section and is on 4′8″ centers. It has a Pittsburg lock seam at one corner and S-and-drive slip connections at each end. Use 1″ = 1′0″ scale and develop a pattern (similar to the one in fig. 63) for this joint. The allowance for the Pittsburg seam is 1¼ inches, and the allowance for the S-and-drive connections is ½ inch at each end of the joint. Include the following on the drawing: dimensions, seam allowances, joint connection allowances, bend instructions, notches, and notching instructions. (7-3, 4, 21, 28; Figs. 60, 63; and Vol. 1)

*4. In figure 64 why do the instructions specify "bend up 180°" on one side of the pattern and "bend down 180°" on the other? (7-5, 31; 2-9; Figs. 64, 12)

5. How much sheet metal will be needed to make (including allowance) the 12-inch joint for the branch line in the latrine shown in figure 60? (7-5; 6-50; Figs. 60, 64)

*6. The following questions concern the transition pattern shown in figure 65. This transition is joint 8 of trunk line B in figure 57.

   a. Why is the triangulation method of layout used to develop this pattern? (7-6; Fig. 65; and Vol. 1)

   b. Why are the stretchouts (not including joint connection allowances) in figure 65 longer than in the plan and elevation views? (7-6; 6-46; Fig. 65)

   c. What is the purpose of the ½-inch "straight" used at the ends of the transition patterns shown in figure 65? (7-6; Figs. 65, 31)

   d. What cutting equipment is best for cutting the joint 8 patterns from sheet 6 shown in figure 59? (7-19; Figs. 59, 65)

   e. What notches are needed at each corner of the top and bottom patterns in figure 65? (7-21, 23; Fig. 65)

   f. Why is step 4 (bending the corners) of the 1–2–3–4 folding sequence *not* needed for the transition shown in figure 65? (7-32, 27; Fig. 65)

7. Joint 12 of trunk line A (fig. 57) and joint 13 of trunk line C (fig. 60) are each 15 inches long and reduce the ducts from 14″ x 8″ to 12″ x 8″; therefore, these joints are identical. Each transition is made in four pieces with Pittsburg lock seams at each corner and with S-and-drive joint connections. The 1-inch Pittsburg seam pocket allowance is on the pattern for the top and bottom, and the ¼-inch Pittsburg seam flange allowance is on the sides. Each end of the joint has a ½-inch "straight" so that the S-and-drive slips will fit properly. The patterns for this transition are developed in a manner similar to that for the transition in figure 65 *except* that it has only two slant sides instead of four.

   a. Develop a pattern for the sides. Include the allowances, dimensions, and bend instructions and show the notching. (7-8, 23, 4; Figs. 57, 65; and Vol. 1)

   b. Develop a pattern for the top and bottom. Make a plan view, elevation view, true length chart, and the pattern. Include the allowances, dimensions, and bend instructions and show the notching. (7-6–8, 23; Figs. 57, 65; and Vol. 1)

*8. Joint 15 of trunk line C in figure 60 has an end cover that is made much like the plenum cover shown in figure 66.

   a. What are the dimensions of the pattern before the allowances are added? (7-9; Figs. 60, 66)

   b. What are the dimensions (including allowances) of the metal needed? (7-9; Figs. 60, 66) *c.* Although the bend instructions are not shown in figure 66, should bends on the cross brake lines be up or down? (7-9, 28, 34; Figs. 60, 66)

9. The end cover for joint 15 of trunk line C (fig. 60) is similar to the plenum cover shown in figure 66. Both have 1-inch standing seams. Use 3" = 1'0" scale to develop a pattern for the end cover for joint 15 of trunk line C, including the dimensions, allowances, bend instructions, notches, and notching instructions. (7-9, 24, 34; Figs. 60, 66)

*10. The latrine and hallway in figure 60 have 8-inch elbows in the branch lines. These 8-inch elbows are similar to the 6-inch elbows shown in figure 61. The following questions concern the 8-inch elbows, each of which has an 8-inch throat radius and five gores.

a. What is the heel radius for the elevation view when you are developing a pattern for an 8-inch elbow to be used in in the branch line of trunk line C? (7-10; Figs. 60, 61, 68; and Vol. 1)

b. Which of the five gores will be half-gores, and which will be whole gores? (7-10; Fig. 68; and Vol. 1)

c. What is the length of the working line of the stretchout for the 8-inch elbow? (7-11; Fig. 68; and Vol. 1)

d. When developing the pattern for an elbow gore, what determines the length of each element line? (7-11; Fig. 68)

e. If the 8-inch elbow patterns are arranged for cutoff like figure 70, which gore will have the allowance for the slip joint? (7-20; Figs. 68, 70)

11. Develop a pattern that can be used for the 8-inch elbows in the latrine and hallway of trunk line C (fig. 57). This pattern will be similar to figure 68, except for the dimensions.

a. Start the pattern development with a 90° angle and 8-inch throat radius. (7-10; Figs. 57, 68; and Vol. 1)

b. Divide the 90° angle into two half-gores and three whole gores. (7-10; Figs. 57, 68; and Vol. 1)

c. Make the 8-inch diameter plan view, divide the circle into 12 equal parts, number the points as in figure 68, and project the points vertically through the miter lines of gore I. (7-10; Figs. 57, 68; and Vol. 1)

d. Draw the working line and the element lines of the stretchout, transfer the length of the element lines from the elevation view, then connect the ends of the element lines with curved lines as in figure 68. (7-11; Fig. 68; and Vol. 1)

e. To the gore stretchout, add the allowance for the 3/8-inch V-grooves and the allowance for the 5/16-inch grooved seam. (7-12; Fig. 68, and Vol. 1)

f. Draw the notches for the stretchout you have made. (7-25; Fig. 68)

12. Take the flat pattern stretchout you have made in the previous exercise and arrange the five gores (with allowances) as in figure 70. Include the dimensions of the metal needed to make the five gores, the prick punch marks, the allowance for the 1½-inch slip joint connection, the ½-inch allowances for the 5/16-inch grooved seam, and the 3/8-inch allowances for the 3/16-inch V-groove. (7-10–12, 20, 25; Fig. 70)

13. All of the following listed items can be used in the fabrication of the round duct joints in foldout 1; however, one is *not* needed on large jobs like this because it is used principally for notching. Which one is not needed? Why?

Squaring shears	Mallet
Straight snips	Hollow mandrel
Pittsburg machine	Crimping machine
Slip roll machine	Beading machine

(7-31, 22; FO 1; and Vol. 2)

14. When the cross brake lines are bent up according to instructions in figure 65, will the ridges be on the inside or outside of the transition? (7-32, 2; Fig. 65)

*15. What three forming machines are used to make the elbow shown in figure 73? (7-35; Fig. 73)

16. When the patterns shown in figure 70 have been cut out and notched, what are the bending instructions for the grooved seams? (7-35, 31; 2-9; Figs. 12, 64, 70)

17. Fill in the blanks. When forming and assembling the gores of 5-piece elbows, the grooved seams can be made with a Pittsburg lock forming machine or with a bar folder and ________________. Like round duct joints, the elbow gores are formed into cylindrical shapes with a ____________ forming machine. After grooved seams are joined and locked, the V-grooves are made with an ________ machine. Care must be exercised to make the inside and outside V-grooves as shown in figure______ so that each gore can be joined. During assembly of the gores, the outside V-grooves in gores II through V are __________ slightly so that they will __________ over the inside V-grooves made in gores I through IV. The V-grooves are locked by setting down the outside groove with a ________________ hammer and ____________ stake. The prick punch marks are used to ________ the gores. After assembly of the gores, a ________ machine and ____________ machine are used to make the slip joint connection. (7-35, 31; 2-9; Figs. 73, 70, 35, 11)

*18. When the tabs are alternately bent 90° on the turn vanes for joint 6 of trunk line A, what should the exact length of each turn vane be? Why? (7-36, 14; Fig. 69)

19. When installing the turn vanes in joint 6 as shown in figure 69, why are 9 installed on the trunk line C side and only 8 on the trunk line B side? (7-36, 14; Fig. 69)

20. In view B of figure 74, are the 14-inch or the 24-inch lengths of the ½-inch S-and-drive allowances bent 180°? Why? Will the 180° bends be up or down? (7-37; Fig. 74)

*21. When forming the flexible connection shown in figure 74, should the double seam be made before or after the 90° corner bends? (7-37; Fig. 74)

Section 8

Objectives: Given duct system data, interpret working drawings and answer questions about duct system components, explain how duct system components and insulation are installed, and determine quantity of materials needed and what tools and equipment are needed.

*1. Refer to the text and foldouts 1 and 2 to answer the following questions.
   a. What is the location of the horizontal centerline of the 18″ x 10″ section of trunk line B? (8-3; FO 1)
   b. What is the location of the horizontal centerline of the 12″ x 8″ section of trunk line B? (8-3; FO 1)

c. How far from the floor is the vertical centerline of trunk line A? (8-4; FO 2)

2. In foldout 1, what is the distance between the horizontal centerline of trunk line C to the center of the ceiling diffusers in the following rooms?
   a. Room 1.
   b. Room 2.
   c. Room 3.
   (8-3; 6-9; FO 1)

3. In room 1 of foldout 1, what is the height (from the floor) of the vertical centerline of the 6-inch branch line? (8-4; FOs 1, 2)

*4. How much 16-gage sheet metal is needed to make the hangers shown in figure 75 if the dimensions of the duct are 10" x 20", the centerline is 25 inches from the rafters, and the hangers lap 4 inches on each rafter? (8-5; Fig. 75)

5. If the 24-gage leftover material from sheet 1 of trunk line B (fig. 59) is used to make duct hangers for trunk line B, how many hangers can be made and what will be their length? (8-5; Figs. 59, 75; FO 1)

*6. What tools and fastening devices should you take to a job to install the strap hangers shown in figure 75? (8-5, 6; Fig. 75)

7. Use figure 57 and answer the following questions.
   a. How many S-slips are needed for installing trunk line B? (8-6; Fig. 57)
   b. How many drive slips are needed for installing trunk line B? (8-6; Fig. 57)
   c. How many hangers will be needed to install trunk line B? (8-6, 10; Fig. 57)
   d. How many hangers will be needed to install the branch lines from trunk line B? (8-6, 12; Fig. 57)

*8. Use figure 53 and answer the following questions about trunk line A.
   a. What joints are connected with tapped connections? (8-7; Fig. 53)
   b. What joints are connected with S-and-drive slips? (8-7; Fig. 53)
   c. If hangers are used to support trunk line A at four locations, what joints will have the hangers? (8-9, 10; Fig. 53)
   d. How far is the vertical centerline of joint 3 from the ceiling? (8-10; Fig. 53; FO 2)
   e. When hanging the joints of trunk line A, what part of each joint is used for alignment with the chalk line which is the horizontal centerline for the duct? (8-10)

9. Use figure 57 and answer the following questions about trunk line B.
   a. What joints are connected with tapped fittings? (8-11, 8; Fig. 57)
   b. What joints are connected with S-and-drive slips? (8-11, 10; Fig. 57)
   c. If hangers are used to support trunk line B at nine locations, what joints will have hangers? (8-10; Fig. 57)
   d. How far above the ceiling are the vertical centerlines of transition joints 2 and 12? (8-10; Fig. 57; FO 2)
   e. How are takeoff fittings for each branch line attached to the trunk line? (8-12; Fig. 57)

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10. Use the illustrations of the round duct branch lines in figures 57 and 61 to answer the following questions.
    - *a.* How many slip joints are in each branch line of trunk line B and where are they located? (8-12; Figs. 57, 61)
    - *b.* If two hangers are used for the branch line shown in figure 61, where would you locate the hangers? (8-12; Fig. 61)
    - *c.* In figure 61, what is the distance between the centerline of the drop joint and the centerline of the trunk line? (8-12; Fig. 61)

*11. You are installing foil-backed glass fiber insulation on rectangular and round duct.
    - *a.* How much allowance is made for the folded seam? (8-15, 18; 6-63)
    - *b.* How much allowance is made for the lap joint between pieces being installed around rectangular or round duct? (8-16, 18; 6-62)

12. Fill in the blanks. Foil-backed insulation 48" wide and 1" thick is to be installed on the duct system shown in figure 57. Three men can do the work efficiently if one man _________ the pieces and two men _________ the pieces around the duct. The piece to wrap around the 18" x 10" joint will be _____ inches long (_______ inch stretchout plus _______ inches for the seam). The pieces to wrap around the 16" x 10" joints will be _______ inches long. The pieces to wrap around the 14" x 8" joints will be _____ inches long. The piece to wrap around the 12" x 8" joints will be _____ inches long (allowing 4 inches for the seam with the 16" x 12" end piece). The material is formed by hand to fit joints _________, ___________, and _________. The material is _________ at joints 3, 4, 5, 7, 9, 11, 12, 13, and 14 to fit around the _________. By slitting the material into two 24-inch widths, the ___________ inch branch lines can be wrapped with one piece extending from the takeoff joint to the ___________. One piece is needed to wrap the ___________ joint, one piece is needed to wrap the ___________ and one piece is needed to wrap the straight joints. The material should ___________ at each end of the elbow. Throughout the system, _________ is used to secure the material. (8-14--18; 6-63, 65; Fig. 57)

*13. Why is it *not* necessary for the return air duct shown in foldout 2 to have 90° flanges such as those shown in figure 49? (8-20; Fig. 49; FO 2)

14. Suppose the latrine door shown in foldout 1 is metal; you are to cut a hole for the return air grille 10 inches on center from the bottom of the door and install the grille.
    - *a.* What size hole should you cut in the door to allow for ⅛-inch clearance on each side of the grille? (8-22; 5-27; FO 1)
    - *b.* If the door is 30 inches wide, where is the location of the scribed lines for the four sides of the hole? (8-21)
    - *c.* What hand snips should you select to cut out the opening in the 24-gage sheet metal door after a slit is made with a ½-inch cold chisel? (8-22; and Vol. 2)

*15. Why is it *not* necessary to have a 90° flange at the duct opening when installing diffusers such as those shown in figure 48? (8-23; 5-22; Fig. 48)

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16. How can you make sure a diffuser such as that shown in figure 48 will be flush with the ceiling if the duct opening is flush with the ceiling? (8-23, Fig. 48)

Section 9

Objective: Given duct system data, interpret working drawings and patterns, answer questions about repair, patching, and replacement of duct system components.

*1. What size disc should be cut to make a patch for a 6-inch round hole in 26-gage sheet metal? (9-2; and Ch. 1)

2. Answer the following questions concerning the patching of a 3-inch hole in a 22-gage sheet metal duct.
   a. What size disc should be cut for the patch?
   b. What is the location of the centerline for the rivet holes?
   c. If tinner's rivets are used as fasteners, what size should be used and what is the maximum distance the rivets should be spaced apart?
   (9-2; 1-5; and Vol. 2)

*3. Answer the following questions concerning the replacement of a flexible connector.
   a. What are four things that you need to know about the old flexible connector before fabricating a new one? (9-5)
   b. How many S-and-drive slips are needed for replacement of a flexible connector that is joined on each end with S-and-drive slips? (9-5; Fig. 56)

4. Use figures 56 and 27 to answer the following questions.
   a. What is the procedure for removal of the old flexible connection? (9-8; Figs. 27, 56)
   b. What is the procedure for installation of the new flexible connection? (9-9; Figs. 27, 56)

*5. Use figure 77 and answer the following questions.
   a. What is the length of joint 12 (center to center)?
   b. What is the width of joint 12 (center to center) at the widest place?
   c. What is the height of joint 12?
   d. How far from the standing S-slip between joints 11 and 12 is the intersection of the trunk line centerline and the branch line centerline?
   (9-11; Fig. 77)

6. Use figures 77 and 78 to answer the following questions.
   a. What are the dimensions of the metal needed to make the top (or bottom) of of joint 12? (9-12; Figs. 77, 78)
   b. What are the dimensions of the metal needed to make each side and heel pattern of joint 12? (9-13; Fig. 78)
   c. What are the dimensions of the metal needed to make each side and throat pattern of joint 12? (9-13, 12; Fig. 78)

*7. When cutting the patterns shown in figure 78, portable unishears are used to cut pattern A, B, or C? (9-13, 12; Fig. 78)

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8. Which pattern (A, B, or C) in figure 78 can be cut more quickly if the back gage of the squaring shears is used? (9-13, 12; Fig. 78; and Vol. 2)

*9. Which of the patterns shown in figure 78 will require use of a slip roll forming machine? (9-15; Fig. 78)

10. In pattern B of figure 78, will the 24-inch radius be rolled up or down? (9-15; Fig. 78)

11. In pattern C of figure 78, will the pocket of the Pittsburg seam be on the side illustrated or on the reverse side? (9-15; Fig. 78)

*12. In figure 77, how many joint connections must be disconnected in order to remove joint 12? (9-16; Fig. 77)

13. In figure 77, if joint 13 extends through a wall and has a register like joints 14 and 15, what must be done to remove joint 12? (9-16; Fig. 77)

*14. When replacing joint 12 shown in figure 77, how many new drive slips should be fabricated and installed? (9-17, 15; Fig. 77)

15. What is the replacement procedure if joint 12 is removed as described in review exercise 13? (9-17, 16; Fig. 77)

16. When replacing joint 12 shown in figure 77, what is the best procedure for installing the new joint if only 1 inch of space can be made between joints 11 and 12? (9-17, 16; Figs. 77, 27)

CHAPTER 4

Section 10

Objectives: Given stack and ventilator data, interpret drawings and answer questions about the effect of wind on stacks and vent caps.

*1. If a stack is located at B in figure 79, will the assistance to the natural draft be the same, better, or nearly as good if the wind shifts 180°? (10-2; Fig. 79)

2. Why should a stack vent cap be high enough to extend above the roof peak of a building? (10-2)

Section 11

Objectives: Given data about stack components and assemblies, answer questions, determine dimensions, and select appropriate components to use.

1. Which joint in figure 81 is best suited to make a 1-inch offset during the installation of a water heater vent? Why? (11-5; Fig. 81)

*2. In what draft position is the double-acting draft diverter blade that is shown in view B of figure 82? (11-7; Fig. 82)

3. At what angle to the floor should a draft diverter be installed in a 45° offset that rises 24 inches from the furnace outlet to the stack? (11-8)

*4. In figure 84, what is the proper length for piece B if piece A is 14 inches. (11-10; Fig. 84)

5. Use figure 84 and answer the following questions about thimble fabrication. In Column A, insert the appropriate number from Column B.

Column A	*Column B*
___ *a.* To form pieces A and B, what seam is best suited? (11-10; 2-5; Fig. 84)	1. Hollow mandrel
___ *b.* What tools and machines should you use to form pieces A and B if a Pittsburgh machine is available? (11-10; 12-20; 7-31; Fig. 84)	2. Slip roll machine
___ *c.* What tools should be used to assemble A and B to form C? (11-10; Fig. 84; and Vol. 2)	3. Tinner's riveting hammer
	4. Mallet
	5. Rivet set
	6. Crimping machine
	7. Portable electric drill
	8. Grooved seam
	9. Pittsburg lock forming machine
	10. Beading machine

6. Which of the five vent caps illustrated in figure 86 is *not* draft diverting and rainproof? Why? (11-14; Fig. 86)

Section 12

Objectives: Given data about stack assemblies, answer questions about corrosion damage, layout, and pattern development, determine solutions for replacement situations, determine dimensions, interpret instructions on patterns, explain fabrication procedures, and explain how components are installed.

*1. Name three stack components (shown in fig. 80) which require replacement more often than others. (12-1; Fig. 80)

2. Determine solutions for the following stack assembly situations.
   a. Some of the components of an old stack assembly need replacement. How can you determine which of the components need replacement? (12-1)
   b. The roof jack and upper stack (such as those shown in fig. 80) are to be replaced. What measurements are necessary to draw a sketch for the installations? (12-1, 3; Fig. 80)

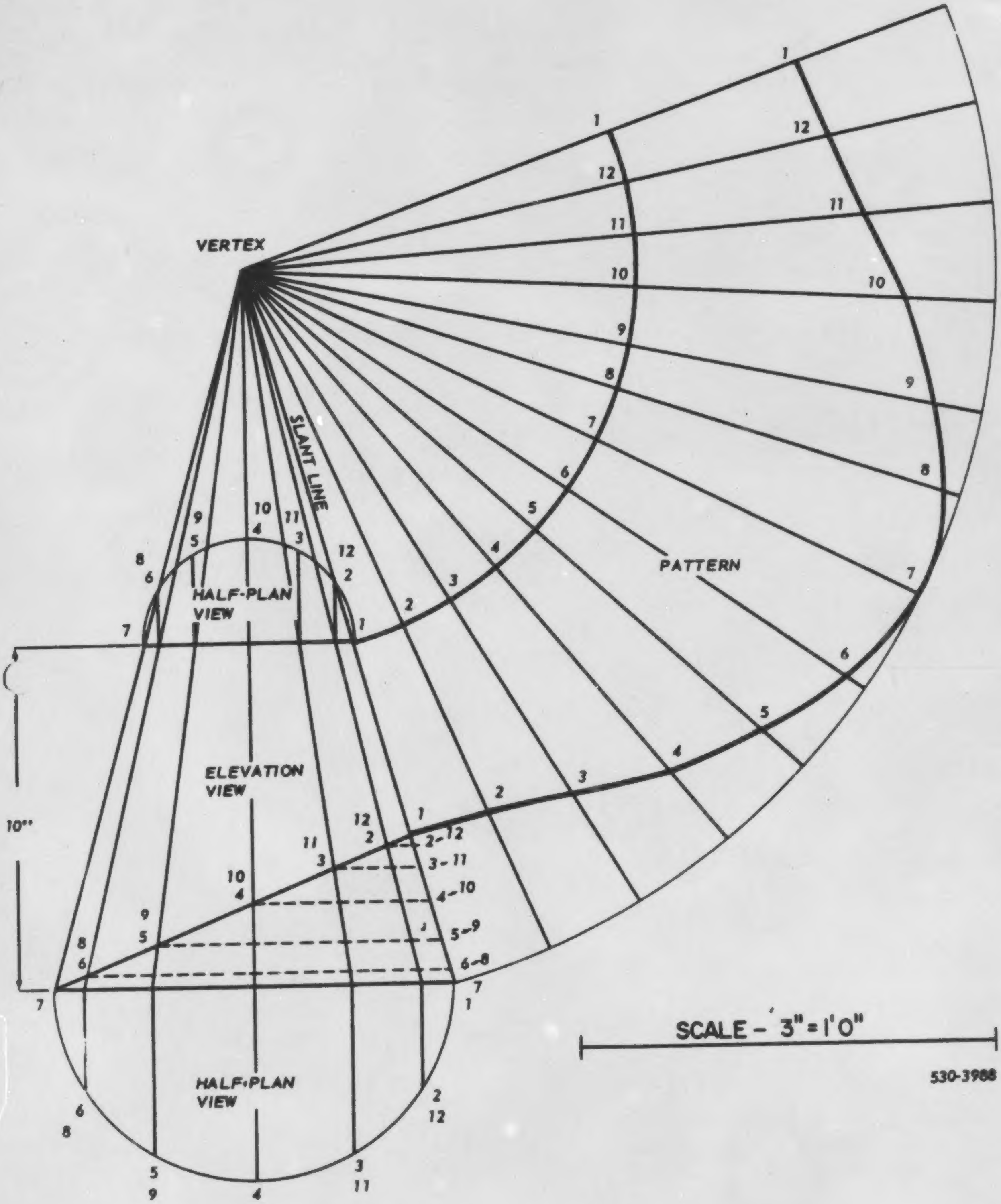
VERTEX
SLANT LINE
PATTERN
HALF-PLAN VIEW
ELEVATION VIEW
10"
HALF-PLAN VIEW
1
12
11
10
9
8
7
6
5
4
3
2
2-12
3-11
4-10
5-9
6-8
SCALE - 3" = 1'0"
530-3988

Figure CRE-3. Roof jack pattern.

c. You need to replace a vent stack assembly. How would you select the proper gage of metal? (12-2)

*3. What layout method should be used to develop a pattern for a roof jack if the base is square and the top is round? (12-5; 13-5; and Vol. 1)

*4. What layout method is used to develop the pattern shown in figure CRE-3 which is for the roof jack shown in figure 80? (12-5; Figs. CRE-3, 80; and Vol. 1)

5. Answer the following questions about the pattern development illustrated in figure CRE-3. Fill in the Column A blanks with the appropriate number from Column B.

Column A

__ *a.* What type of frustrum is shown in the elevation view?
__ *b.* Why are the element lines projected to the slant line?
__ *c.* Why are the element lines different lengths?
__ *d.* Why are element lines 1 and 7 *not* projected to the slant line?
__ *e.* Why is it necessary to draw the element lines on the pattern?
__ *f.* What would happen if the distance from the vertex to points 4–10 was used to make the element lines 5–9 on the pattern?

Column B

1. Regular frustum
2. To conform with the truncated line
3. Irregular frustum
4. To determine true lengths
5. Because they are true length lines
6. The element lines would be too long
7. The element lines would be too short
8. So the true length can be marked

(12-5; Fig. CRE-3; and Vol. 1)

6. Why is it *not* necessary to have a draft diverter on the stack assembly shown in figure 80? (12-7, 4; Fig. 80; and Vol. 1)

7. What is the cutout length (arc) for a vent cover cap top (similar to A in fig. 89) that is 10 inches in diameter and 2 inches high? (12-8; Fig. 89; and Vol. 1)

*8. Answer the following questions concerning the fabrication of the ceiling thimble shown in figure 90. Fill in the Column A blanks with the appropriate numbers from Column B. (Not all numbers in Column B will be used.)

Column A

__ *a.* What machine is best suited to cut out the rings? (12-12,18; Fig. 90, and Vol. 2)
__ *b.* What machine is best suited to punch the $\frac{5}{16}$-inch air holes in the rings? (12-12; Fig. 90; and Vol. 2)
__ *c.* What two punches can be used for the screw holes in the rings? (12-12; Fig. 90; and Vol. 2)
__ *d.* What machine should you use to form the sleeves? (12-13, 22; Fig. 90; and Vol. 2)
__ *e.* What should be used to make the screw holes in the ½-inch flange if the ring and sleeve are spot-welded before the holes are made? (12-12; Fig. 90; and Vol. 2)
__ *f.* Should the holes in the ½-inch flange be larger or smaller than

Column B

1. Slip roll forming machine
2. Whitney punch
3. Rotary punch
4. Center punch
5. Spot welding machine
6. Bar folder
7. Portable electric drill and twist drill
8. Larger
9. Smaller
10. Ring and circle shears
11. Circle shears

Column A *Column B*

the sheet metal screws? (12-28; Fig. 90; and Vol. 2)

___ *g.* What machine should you use to form the 1" x 1" angle tabs shown in views B and D? (12-23; Fig. 90; and Vol. 2)

___ *h.* What machine should you use to fasten the rings to the sleeve flanges? (12-26; Fig. 90; and Vol. 2)

9. A ceiling thimble such as that shown in figure 90 is to be made for a 6-inch double wall stack.
   a. What will be the diameter of the inside hole of the thimble ring? (12-12; 11-3, 5; Fig. 90)
   b. What will be the outside diameter of the ring pattern if made for a 2-inch airspace? (12-12; Fig. 90)

10. Fill in the blanks. The pattern for the brace piece shown in view B of figure 91 has four lines that are to be bent 90°. Looking at the pattern, you will see that the first line on the left should be bent ____________, the second line bent _____, the third line bent _________, and the fourth line bent ___________. Next, look at the pattern in view C of figure 91. The first line on the left should be bent _______, and the second line should be bent _______. (12-15; Fig. 91)

*11. What machine should be used to form the pattern shown in figure CRE-3 into the shape of the roof jack? (12-19; Fig. CRE-3)

*12. When the pattern shown in figure CRE-3 is formed and assembled with a grooved seam, how much of the seam should be soldered? (12-24; Fig. CRE-3)

13. When a roof jack and a base are joined with dovetail seams, are the tabs bent in the same direction or in opposite directions? Why? (12-24; Fig. 17)

*14. In figure 80, which tool should you use to locate the centers for the thimble and roof jack holes? (12-27; Fig. 80)

15. If the stack assembly in figure 80 is being installed using double-wall vent stack, what is the mistake if the vertical centerline of the roof jack and ceiling thimble line up but the stack is 1 inch off center of vertical centerline of the heating unit collar? Which fitting in figure 81 should be used to correct the mistake? (12-27; Figs. 80, 81)

Section 13

Objectives: Given data about ventilators, answer questions about layout, fabrication, and installation, select appropriate components and determine dimensions, size of rivets, and how to run patterns through forming machines, and solve problems about fabrication and installation.

*1. Which ventilator in figure 92 can be installed below the roof peak and still operate efficiently? (13-1; Fig. 92)

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*2. What layout method would you use to develop a pattern for the replacement of a roof ventilator such as that shown in view B of figure 92? (13-5; Figs. 92, 93)

3. In the elevation view of figure 93, a 5 to 12 pitch is shown, and the distance from the base line to point CD is 2½ inches. What would this distance be if the pitch is changed to 3 to 12 and the base is changed to 8" x 8"? (13-5; Fig. 93, and Vol. 1)

*4. If the 22½° bend lines on the pattern shown in figure 94 are formed on the cornice brake, at what angle will line BC be to base line AB? (13-8; Fig. 94)

5. The half pattern in figure 94 is run through the Pittsburg lock forming machine, and the grooved seam pockets are on the side on which the 22½° lines will be bent up. How should the second half of the pattern be run through the Pittsburg machine so that the grooved seams can be joined? (13-8; Fig. 94)

*6. If the corner clips are to be spot welded and soldered when you are assembling the two half transition patterns shown in figure 94, will the surfaces need to be tinned? (13-9; Fig. 94; and Vol. 2)

7. When the two half patterns (shown in fig. 94) are assembled, the 24-gage flashing will have gaps at each corner which are 4" x 4". These gaps are covered with 24-gage corner clips that flat lap over the edges of the flashing which are secured with thinner's rivets. What will be the dimensions of each corner clip, and what size tinner's rivet should be used? (13-9; 1-4, 5; Fig. 94)

*8. The ventilator shown in view B of figure 92 is being installed on an asphalt shingle roof; what should be used around the flashing to prevent leaks? (13-13; Fig. 92)

9. What size hole should be made in the roof to install the draft ventilator made from the pattern shown in figure 94? (13-13, 4; Fig. 94)

CHAPTER 5

Section 14

Objectives: Given the data about hoods, interpret working drawings and instructions; determine dimensions and pattern additions; and answer questions about forming, assembly, and installation.

*1. In figures 97 and 98, what are the lengths of the following lines?
   - *a.* A–B.
   - *b.* A–D.
   - *c.* 7–10.
   - *d.* 1–2.
   - *e.* F–4.

   (14-5–8; Figs. 97, 98)

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2. In figures 97 and 98, what are the equivalent lengths of the following lines?
   a. A–7.
   b. A–4.
   c. B–8.
   d. B–2.
   (14-5–8; Figs. 97, 98)

*3. How much metal should be added to the pattern of the front side in figure 98 for the addition? (14-9; Fig. 98)

4. What are the dimensions of the sheet metal needed to make the front piece, including seam allowances and additions, of the hood shown in figure 98? (14-9, 11; Fig. 98)

*5. Fill in the blanks. When forming the front pattern shown in figure 98, the standing seams will be bent ______, the 180° bend for the hem will be __________, the 90° bend for the ½-inch flange will be _____, the 90° bend for the grease trap will be ________, the 10° bend for the skirt will be ________, and the 10° bend for the collar will be ________. (14-13; Fig. 98)

6. In figure 98, will the instructions written for the back pattern and right side pattern be on the inside or outside when the hood is assembled? (14-13; Fig. 98)

*7. When assembling the standing seams of the four pieces of the hood shown in figure 98, which pieces will fit into the seam pockets of the side pieces? (14-15; Fig. 98)

8. When the patterns shown in figure 98 are assembled, the pieces are joined with standing seams, lap seams, and butt joints. Where are the butt joints located? (14-15; Fig. 98)

*9. When the patterns shown in figure 98 are assembled, how many Monel rivets will each of the standing seams have? (14-15; Figs. 97, 98)

10. How many Monel rivets are used to assemble the hood shown in figure 96? (14-15–19; Figs. 96, 99)

*11. Why is the adhesive paper *not* removed from the stainless steel until one of the last steps in the installation procedure? (14-21, 3)

12. What size filter is used with the hood shown in figure 96? (14-21; Fig. 96)

Section 15

Objectives: Given data about serving line equipment, interpret working drawings, determine dimensions of replacement components, and answer questions about grinding and buffing stainless steel.

*1. If the front panels shown in figure 100 are 36 inches long and 30 inches wide, what will be the dimensions of the metal to make a replacement panel (including flange)? (15-8; Fig. 100)

2. What diameter and what length of brass round stock is needed to make the splice shown in figure 102 if the wall of the tray slide rail tubing is 14 gage (0.064 inch thick)? (15-12, 4; Fig. 102)

3. You are to make a tray slide rail bracket similar to the one shown in figure 103, but with different dimensions. What will determine the distance between the centers of the holes to be punched in the pattern? (15-14; Fig. 103)

*4. What will be the dimensions of a piece of sheet metal to make the single pattern for the front, sloping top, top, and back of the silverware holder shown in figure 104? (15-15; Fig. 104)

5. What will be the angles of the three V-notches which are along the sides of the pattern shown in view C of figure 104?
   a. Front upper corner.
   b. Top front corner.
   c. Top back corner.
   (15-16, 17; Fig. 104)

6. The 5-inch circular cutouts will be ½ inch from the edges of the 12″ x 20″ sloping panel.
   a. How far from the upper edge of the sloping top will the two horizontal centerlines for the circles be located?
   b. How far from the left side of the sloping top will the three vertical centerlines for the circles be located?
   (15-16; Fig. 104)

*7. What should you do before grinding a stainless steel weld if the grinding wheel has been previously used to grind a weld on an angle iron frame? (15-22)

8. When buffing stainless steel, will a number 4, 6, or 7 finish have the brightest luster? Why? (15-25)

Section 16

Objectives: Given data about shower stalls, interpret patterns and instructions, answer questions about patterns, seams, rivets, and disassembly procedures, and determine settings for forming machines.

*1. One edge of the pattern for the side pieces shown in figure 106 shows two additions for flanges and one allowance for the $\frac{5}{16}$-inch hem.
   a. What is the width of the flange next to the pattern?
   b. What is the width of the flange next to the hem?
   (16-2; Figs. 105, 106)

2. The pattern for the side pieces shown in figure 106 does not show the dimensions

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of the flange additions nor the hem allowance.

a. How long is the square notch at the top of the pattern for the side piece?

b. How long is the square notch at the bottom of the side piece?

c. How long are the additions and allowances that have square notches at each end?

(16-2; Figs. 105, 106)

3. The bends on the four sides of the top and bottom pieces shown in figure 106 should be made on a box and pan brake. At what width should the fingers of the box and pan brake be set? (16-4; 106; and Vol. 2)

*4. What corners of the shower stall shown in in figure 105 are assembled with Pittsburg lock seams? (16-7; Figs. 105, 106)

5. The shower stall shown in figure 105 has one row of rivets missing. Which row is missing? (16-7; Fig. 105)

*6. When replacing the bottom of the shower stall shown in figure 105, should you drill the rivet heads from inside or outside the shower stall? Why? (16-11; Fig. 105)

7. A damaged side of the shower stall shown in figure 105 is to be removed and replaced with a new one. Will the top end or the bottom end of the side be the most difficult to disassemble? Why? (16-11; Fig. 105)

Section 17

Objectives: Given data about fireproof partitions and doors, answer questions about seams and fabrication, determine dimensions, size, and quantity of sheet metal; determine kind of cutting equipment to use; and explain how damaged pieces are removed and how replacements are installed.

*1. What are two methods that may be used to join sheet metal when covering partitions for fireproofing purposes? (17-3, 4)

2. You are covering a partition with galvanized sheet metal for fireproofing purposes. If the wall studs are on 16-inch centers and the ceiling is 8 feet high, what size sheets should you use? (17-4)

*3. How many pieces of formed sheet metal are needed to cover the fire door shown in figure 107? (17-5, 6; Fig. 107)

4. What tools and equipment are needed to cut and form the patterns for the door covering pieces shown in figures 108 and 109? (17-6; Figs. 108, 109; and Vol. 2)

5. Why is the hand seamer needed to bend the 90° flanges at the mitered ends of the top, bottom, and side pieces of the door

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covering shown in figure 108? (17-6; Fig. 108)

*6. What kind of seam is used for a patch that is to be nailed over a damaged portion of a sheet metal covered door? (17-17; 1-3)

7. You are assigned to repair the metal covering of the door shown in figure 107. The side piece on the door knob side is to be removed and replaced with a new piece.
   a. How is the damaged piece removed?
   b. When the piece is removed and flattened out to make a duplicate pattern, will the piece look like A, B, C, or D in figure 108?
   c. How long and how wide (including seam allowances) will the replacement pattern be?
   (17-18, 8; Figs. 107, 108)

Section 18

Objectives: Given data about installation of factory-made awnings, explain how the screw holes are spaced and determine what tools are needed for the job.

*1. When installing a factory-made awning, such as that shown in figure 110, on a wooden window frame, how is the spacing determined for the screw holes to be made in the window facing so that the weatherstrip can be installed? (18-3; Fig. 110)

2. What tools are needed to assemble and install the factory-made awning shown in figure 110 on a concrete (cinder) block building? (18-2–4; Fig. 110)

Section 19

Objectives: Given data about canopies, interpret patterns and determine size of rivets and screws, answer questions about patterns, cutting procedures, and removal and replacement procedures.

*1. View B in figure 113 shows the pattern for the side trim of a canopy. The ends of the patterns have allowances for a ½-inch CORNER LAP SEAM. Why does the pattern show a 1-inch allowance at each end? (19-4; 1-4; Fig. 113)

2. Which patterns (A through G) will require the use of straight snips? (19-8; Fig. 113)

*3. What bends shown in figure 113 should be made with a mallet instead of the cornice brake? (19-10; Fig. 113)

4. If the corner brackets shown in figure 112 are installed with aluminum rivets which have shanks ¼ inch in diameter, how long should the rivet shanks be? (Use the same length rivets for the front and sides. The rivet should extend through the metal about 1½ times the diameter of the rivet.) (19-11; Fig. 112; and Vol. 2)

*5. What size screws (with expandable sleeves) are needed to attach the canopy parts to the cinder block wall shown in figure 112? (19-12, 13; Fig. 112)

6. It is possible to remove and replace one of the inside panels of the top of the canopy (shown in fig. 112) without removing the canopy from the building. Would it be better to remove the canopy to do the job? Why? (19-19, 20; Fig. 112)

CHAPTER 6

Section 20

Objectives: Given data about metal roofing, answer questions about kinds and shapes of metal roofing, types of roofing seams, fabrication of metal roofing, and installation of metal roofing; explain the procedure for removing and installing roofing sheets; determine dimensions, spacing of rivets and cleats, tools needed, and sequence for removing and replacing roofing sheets.

*1. Why is a layer of asphalt-saturated felt used between the laps of different kinds of metal? (20-3; and Vol. 1)

2. If you are installing a galvanized metal roof, which of the following fasteners should be used: aluminum sheet metal screws, cadmium-plated sheet metal screws, or copper-coated sheet metal screws? (20-3, 7)

*3. Will copper sheets, galvanized sheets, or black iron sheets last the longest on a roof? (20-5; and Vol. 1)

4. A permanent base chapel is being constructed and a long-lasting metal roof with batten seams is to be installed. What metal should be used? (20-5)

5. Is a grooved (flat) seam or a standing seam more likely to leak when used on a roof with a 2 to 12 pitch? Why? (20-10, 12)

*6. If a working drawing specifies that expansion joints be installed at 30-foot intervals, which of the following seams would be used to install the metal roofing: grooved (flat) seams, batten seams, or standing seams? (20-10, 12, 15)

*7. What roofing tool should you use to make a ¾-inch standing double seam? What size of roofing tool? (20-19)

8. In figure 116, what roofing tool should be used in steps C, D, and E if the seam in step F is to be 1 inch high? What size of roofing tool? (20-19; Fig. 116)

*9. What type and shape of metal roofing is being installed in figure 124? (20-24, 6; Fig. 124)

10. Which corrugated sheet (A, B, C, D, or E) shown in figure 124 should be installed first if the prevailing wind is from the opposite direction? (20-24, 25; Fig. 124)

11. If a 2½ corrugation sidelap is being used on the sheets shown in figure 124, how far apart will the sheet metal screws be spaced? Will the screws be on the outside crown or on the second crown? (20-25; Fig. 124)

*12. When installing a metal roof (such as that shown in view E of fig. 126) with cleats, how far apart will the cleats be spaced? (20-32, 12; Fig. 126)

13. Answer the following questions about the fabrication and installation of the ridge cap shown in view E of figure 126.
    a. How many cleats should you use to fasten the two halves of the ridge cap if the ridge is 48 feet long? (20-32, 12; Fig. 126)
    b. What is the stretchout of each half of the ridge cap if ¾-inch grooved seams are being used to install the roof? (Use 1/16 inch for the thickness allowances of both types of seams.) (20-32; 2-13, 3, 6; Fig. 126)
    c. Why can't the double seamer be used to make the final fold and to flatten the seam on the ridge? (20-33, 19; Fig. 126)

*14. If you are to repair a small hole in a copper roof, what tools and equipment will you need besides soldering coppers, fire pot, solder, acid, and acid brush? (20-44; and Vol. 2)

15. If the roof shown in figure 124 is galvanized iron, what is the procedure for removal of sheet B and installation of a new replacement? (20-45, 25, 26; Fig. 124)

Section 21

Objectives: Given data about flashing, identify types of flashing, interpret working drawings, and answer questions about using the cornice brake; determine type of seams to use, number of joints needed, amount of material for expansion joints, dimensions of flat pattern stretchout, and what tools are needed.

1. You are using the cornice brake to form the gable flashing shown in view C of figure 127. When the 180° bottom pocket is formed, what is the maximum bend that you can make for the top pocket before installation? (21-5; Fig. 127)

2. You have used the cornice brake to form gable flashing like that shown in view C of figure 127. The 180° pocket for the bottom edge strip and the 90° flange for the beginning of the standing seam are completed. During the installation of the flashing, what roofing tool is best suited

to form the 1-inch double standing seam? (21-5, 20-19; Fig. 127)

*3. What types of flashing are shown in figure 127? (21-5, 6, 7; Fig. 127)

*4. What is the pattern stretchout of the eave flashing shown in view C of figure 126 if the flashing is to extend 4 inches over the ⅝-inch roof deck and is fastened with a ¾-inch grooved (flat) seam? Two seam widths of the grooved seam will be made on the roofing sheet. (21-6; Fig. 126)

5. The straight joints of fascia and gravel guard shown in figure 130 are in 24-foot sections of 8-foot copper joints. How will the ends of the three joints (1, 2, and 3) be formed? (21-9, 10; Fig. 130)

*6 How many expansion joints should be fabricated for the flashing shown in figure 130 if it is made of aluminum and the distance is 40 feet between corner pieces? (21-17; Fig. 130)

7. The installation of aluminum fascia and gravel guard flashing shown in figure 130 involves the use of expansion joints, such as that shown in figure 132. How far will each side of the flashing lap over piece A of the expansion joint if a ¼-inch expansion allowance is made? (21-17, 4; Figs. 130, 132)

Section 22

Objectives: Given data about gutters and downspouts, answer questions and solve problems about fabrication and installation and determine pattern dimensions, material needed, and bends to be made.

*1. What gutter components shown in figure 134 change the direction of water flow in the gutter? (22-3; Fig. 134)

2. How long should the spike and ferrule be be if you are installing a 5-inch ogee box gutter? (22-8; Fig. 136)

*3. The gutter for the 6-foot front of the building shown in figure 134 is a straight section. Why is it necessary to use a chalk line during installation? (22-20, 21; Fig. 134)

*4. Which hanger braces shown in figure 136 will allow a gutter to be raised and lowered during installation without changing the location of the bracket? Why? (22-21, 9; Fig. 136)

5. How many hangers should be installed on the front of the building shown in figure 134 if the distance between the end cap and the outside corner miter is 7 feet instead of 6 feet? (22-21; Fig. 134)

6. If the distance between the inside and outside corners of the building (in fig. 134) is 3′ 6″ instead of 3′, what should be the length of the straight gutter between the inside and outside corner miters? (22-22; Fig. 134)

7. In figure 134 the distance between the end cap and the outside corner miter slip joint is 65½ inches. How much allowance (approximately) should be made for expansion of the galvanized iron gutter? (22-23; 20-2; Fig. 134)

*8. Why is the pattern stretchout 15 inches for the 6-inch ogee box gutter which is shown in figure 139? (22-29; Fig. 139)

9. Answer the following questions concerning the fabrication of a 5-inch ogee box gutter such as shown in figure 139.
   a. What is the pattern stretchout? (22-29; Fig. 139)
   b. How many 10-foot lengths of 5-inch ogee box gutter can be made from a 3′ x 10′ sheet of metal? (22-29; Fig. 139)
   c. In what sequence should the ogee box gutter be formed on the cornice brake? (22-31, 32; Fig. 140)

10. What bends are necessary if you are to fabricate the box gutter with straight sides which is shown in figure 135? To find the answer to this exercise, make an end view of the box gutter and number the bends similar to those in figure 140. (22-31, 32; Figs. 135, 140)

11. You are to form a box gutter with straight sides like the one shown in figure 135. The front side is 60° to the bottom of the gutter. Use the appropriate bends from figure 141, and determine what angle each bend will be. (22-31, 32; Figs. 135, 141)

*12. If the gutter shown in figure 144 is changed so that piece 1 is the low end and has the drop outlet, what changes will be necessary for the flanges and tabs on the corner miters? (22-37; Fig. 144)

*13. In figure 146, why is the distance between the notches 7½ inches when the downspout is located 8 inches from the wall? (22-41; Fig. 146)

14. In view A of figure 146, the distance between notches is 7½ inches. What will this distance become if a 4-inch offset is to be made? (22-41; Fig. 146)

*15. In view A of figure 146, two 22½° miters make the 45° notches. What miter angles are necessary if the notches are to be 30°? (22-41; Fig. 146)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

Section 1

1. For 24-gage sheet metal, the seam allowance for a flat lap seam will be ⅜ inch on each of the edges to be joined. (1-5; Figs. 1, 6)
2. *a.* Circumference of 12.565 inches plus 1-inch seam allowance equals 13.565 inches. (1-6, Figs. 1, 6)
    b. ½ inch. (1-6; Fig. 1)
    c. The holes are 3½ inches apart, and the end holes are each ½ inch from the ends of the metal. (1-6)
    d. 22 rivet hole locations (11 on each edge). (1-6)

Section 2

1. Standing seams made across the top or bottom of duct joints will reduce vibration. (2-2)
2. The allowance for the folded side will be 2 1/16 inches. (2-3; Fig. 18)
3. The vertical leg should measure 2 1/16 inches. (2-4; Fig. 8)
4. Although a grooved seam resembles a standing seam which has been bent over, the allowance for the metal thickness is more for the grooved seam because of the metal needed to form the groove. (2-5; Fig. 11)
5. The grooved seam allowance will be approximately 1 9/16 inches. (2-6; Fig. 18)
6. One edge should be turned up 180° and the other edge down 180° so that the sheets will lock together when overlapped. (2-9)
7. The grooved seam and Pittsburg lock seam. (2-11, 20)
8. An allowance of 1 11/16 inches should be made for a grooved seam made on a Pittsburg lock forming machine. (2-11, 6; Fig. 18)
9. The height of the flanged edge of piece 1 should be ⅜ inch because the channel of piece 2 is ⅜ inch deep. The 90° flange does not require a bend allowance. (2-14; Figs. 13, 18)
10. The thickness allowance (2T) must have been added to piece 1 instead of piece 2. (2-14, 3; Fig. 18)
11. The total seam allowance will be 1 3/16 inches. (2-16; Fig. 18)
12. With the seam allowance included, the 12-inch side will measure 12½ inches, and the 18-inch side will measure 19⅛ inches. (2-16; Fig. 18)
13. The depth gage bar must be adjusted to ¼-inch depth; then with a similar movement to step A in figure 10, the metal is folded to 90°. The 180° bend of the corner double seam can be formed as shown in step B of figure 10; however, allowance must be added for the bend so that the depth of the fold will be ¼ inch. (2-17; Fig. 10)
14. Burring; 13⅛; burring; ¼; tinner's setting; mallet; ¼; setting down; double seaming stake. (2-19; Fig. 15)
15. Thickness gage; 15/16, 1 or 1 1/16; flush; B; A; bar folder; lock. (2-20, 21, 24; Fig. 16)
16. See figure CRE Ans–1. (2-23; Figs. 8, CRE–1, CRE–1, CRE Ans–1)
17. Because a lap seam would require an outside flange to be turned on the cylinder, the flange would have to be riveted or spotwelded to the base. If a dovetail seam is used, the two pieces can be fastened with the tabs. (2-26, 19; Fig. 16)
18. The tabs should be cut ½ inch for the dovetail seam. The miter for the T-joint will not have any affect on the seam (2-26; Fig. 17)

Section 3

1. The standing seam can be used as a joint connector or as a seam for connecting two sheets of metal. (3-3; 2-2)
2. The standing seam allowance is 3 1/16 inches; therefore, piece 1 should be 31 inches long and piece 2 should be 32 1/16 inches long. (3-4, 2-3; Figs. 18, 20)
3. An S-slip that allows 1-inch overlap will require only ½-inch allowance for each sheet being joined because the overlap is measured from the center of the S-slip. For example, look at figure 21 and assume that pieces 1 and 2 make a total length of 8 inches. If each piece is cut 4½ inches long and inserted into the S-slip, the total length will be 8 inches. (3-6; Fig. 21)
4. The standing S-slip would be best suited. The standing S-slip is recommended in figure 28 for ducts up to 24 inches wide. (3-8; Figs. 22, 28)
5. A piece of 6″ x 13¾″ sheet metal is required. (3-9; Fig. 23)
6. The brake line was missed in the last bending operation. (3-9; Fig. 23)

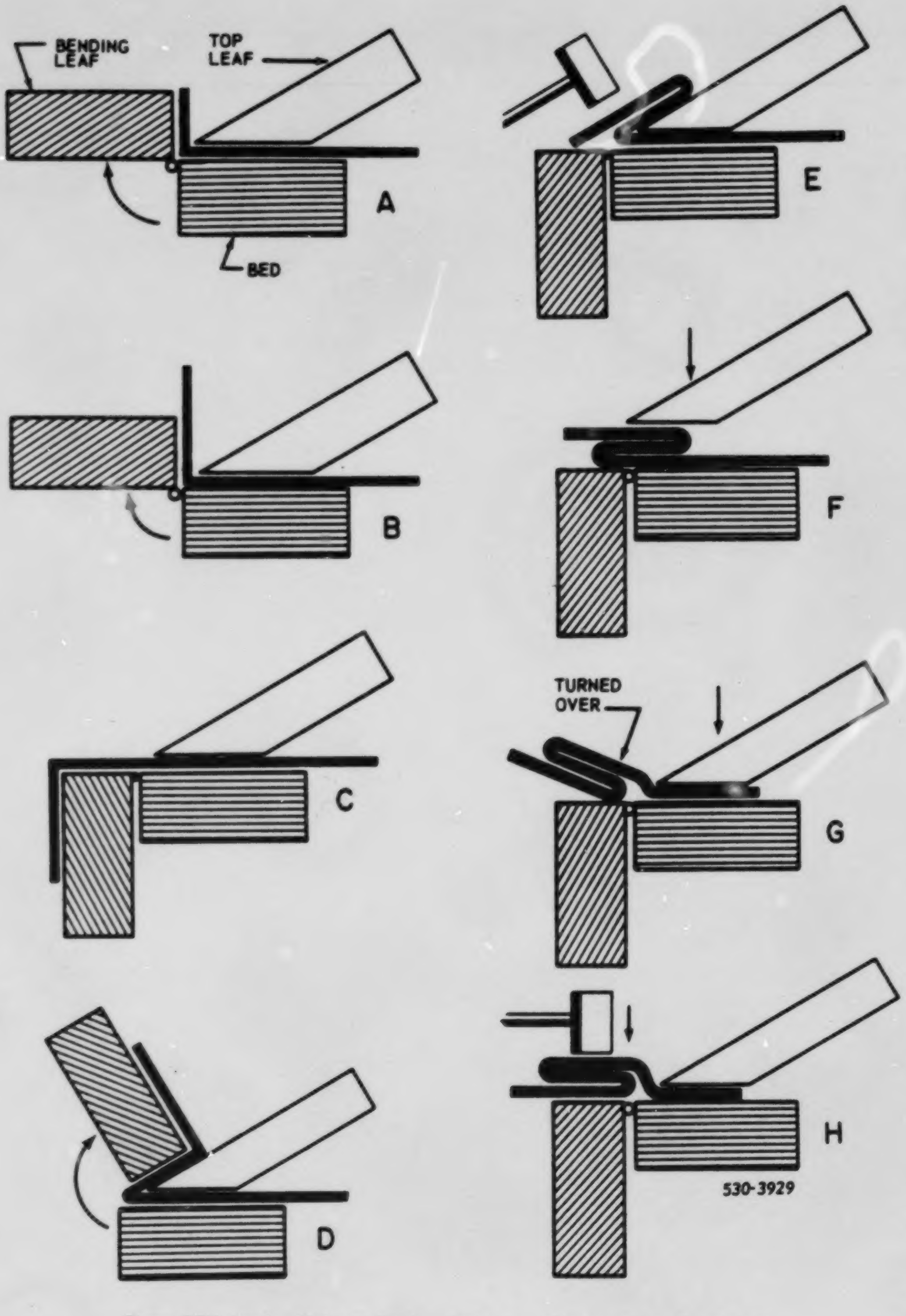

BENDING LEAF
TOP LEAF
BED
A
B
C
D
E
F
TURNED OVER
G
H
530-3929

Figure CRE Ans–1. Making a Pittsburg lock seam with a cornice brake and mallet.

7. The pattern will be 21¾ x 5½ inches. (3-11, 9; Fig. 23)
8. The first edge which was bent 180° will be 9/16 inch wide instead of ½ inch. The second edge will also be 9/16 inch wide. The opening which should be ⅛-inch wide will not be a gap at all because the two edges will meet. (3-15; Fig. 26)
9. The drive slip is not wide enough or the gap between the folded edges is too small. (3-18; Fig. 27)
10. A standing S-slip. (3-22; Fig. 28)
11. Use heavier gage sheet metal, brace with cross brake bends, and use angle iron braces or standing seams across the center of each joint in the duct. (3-22; Fig. 28)
12. The material required for the tapped connector is 3 inches. (3-24; Fig. 29)
13. *a.* Throat pattern is 9¾ inches long.
    b. Heel pattern is 16 inches long. (3-24, 16, 6; Fig. 29)
14. *a.* Six notches.
    b. Six (45°) notches and four (90°) notches.
    c. Two slits.
    d. Two slits.
    (3-30; Fig. 32)
15. See piece 1 (top pattern) in figure CRE Ans–2. (3-30, 29; Figs. CRE–2, CRE Ans–2)
16. See piece 2 (left side pattern) in figure CRE-Ans–2. (3-30, 29; Figs. CRE–2, CRE Ans–2)
17. See piece 3 (right side pattern) in figure CRE Ans–2. (3-30, 29; Figs. CRE–2 CRE Ans–2)
18. See piece 4 (bottom pattern) in figure CRE Ans–2. (3-30, 29; Figs. CRE–2 CRE-Ans–2)
19. The Pittsburg lock seam pockets should be formed first. (3-31, 37; Figs. CRE–2)
20. The inside surface will be facing up. (3-32; Figs. 32)
21. The pattern should be run through the Pittsburg lock forming machine with the pattern in the position shown in figure 32. If it is turned over, the pockets will be on the wrong side. (3-37; 2-24; Figs. 32)
22. The fourth step is to make the corner bends. The bottom piece does not have any corner bends. (3-37, 31; Figs. 32)

CHAPTER 2

Section 4

1. The 20″ x 30″ duct will deliver more air because it is closer to being square than the 15″ x 35″ duct. (4-4, 5)
2. When the size or shape of a duct must be altered, make the change as slight as possible. (4-4, 7; Fig. 37)
3. A round duct has better airflow characteristics than square or rectangular ducts. (4-5)
4. The diverging transition will require splitters. (4-7; Fig. 37)
5. The inside radius ratio will be 0.5, or $\frac{R}{W} = \frac{10}{20} = \frac{1}{2} = 0.5$. (4-10; Fig. 38)
6. A throat radius of 16 inches would be best for more airflow. (4-10; Fig. 38)
7. A bend (throat) radius of 18 inches will raise the inside radius ratio to 1, or $\frac{R}{W} = \frac{18}{18} = \frac{1}{1} = 1$. (4-10; Fig. 39)

Section 5

1. The 9-inch inside passage will have an inside radius ratio of 0.66, or $\frac{R_1}{W} = \frac{6}{9} = \frac{2}{3} = 0.66$. The 9-inch outside passage will have an inside radius ratio of 1.66, or $\frac{R_2}{W} = \frac{15}{9} = \frac{5}{3} = 1.66$. (5-3; Fig. 39)
2. The stretchout for each turn vane will be 11.5696 (approximately 11 9/16) inches wide. (5-8, 9; Fig. 41)
3. *a.* The stretchout, including allowances, will be 15½ inches long by 7¾ inches wide. (5-8, 9; Fig. 43)
   b. Mathematically, 6.6 turn vanes are needed, but since a fractional turn vane is impossible, it would be practical to use 6 turn vanes and space them approximately 3 9/32 inches apart. (5-8; Fig. 41)
   c. Three tabs are needed for each end, making a total of six. (5-10)
4. A deflecting damper should be installed at the branch line entrance to pick up more air. (5-12; Fig. 43)
5. The deflecting damper will be approximately 9¾ inches long and 6 inches wide. (5-13; Fig. 42)
6. The control handle would be installed 90° wrong. If the control handle is positioned 45° to the left of straight down, the blade should be vertical and the duct closed. (5-16; Figs. 43, 44)
7. *a.* The damper blade should be 15¾ inches long and 11¾ inches wide. (5-15)

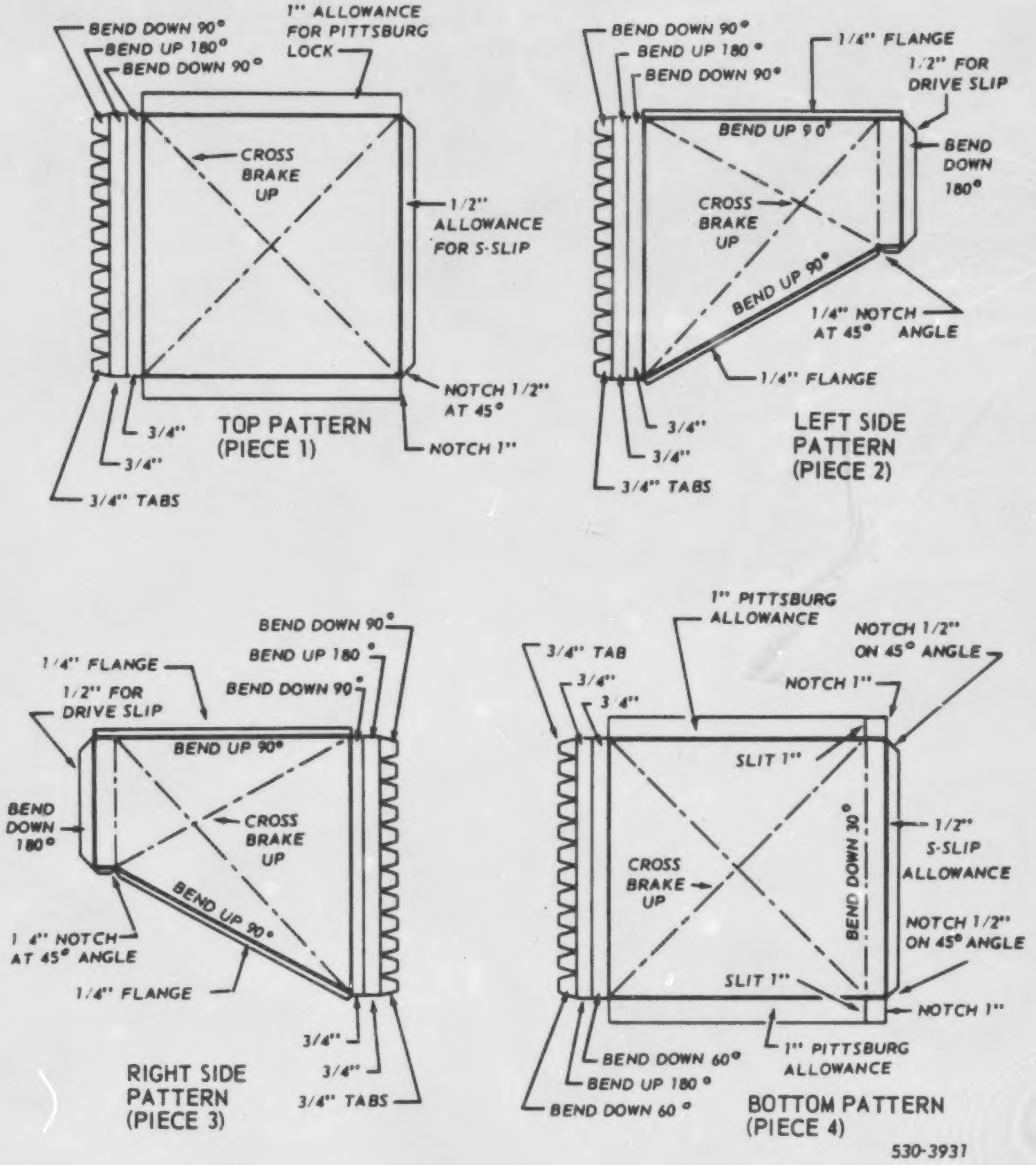

BEND DOWN 90°
BEND UP 180°
BEND DOWN 90°
1" ALLOWANCE FOR PITTSBURG LOCK
CROSS BRAKE UP
1/2" ALLOWANCE FOR S-SLIP
NOTCH 1/2" AT 45°
NOTCH 1"
3/4"
3/4"
3/4" TABS
TOP PATTERN (PIECE 1)
BEND DOWN 90°
BEND UP 180°
BEND DOWN 90°
1/4" FLANGE
1/2" FOR DRIVE SLIP
BEND UP 90°
BEND DOWN 180°
CROSS BRAKE UP
BEND UP 90°
1/4" NOTCH AT 45° ANGLE
1/4" FLANGE
3/4"
3/4"
3/4" TABS
LEFT SIDE PATTERN (PIECE 2)
BEND DOWN 90°
BEND UP 180°
BEND DOWN 90°
1/4" FLANGE
1/2" FOR DRIVE SLIP
BEND UP 90°
BEND DOWN 180°
CROSS BRAKE UP
BEND UP 90°
1/4" NOTCH AT 45° ANGLE
1/4" FLANGE
3/4"
3/4"
3/4" TABS
RIGHT SIDE PATTERN (PIECE 3)
1" PITTSBURG ALLOWANCE
3/4" TAB
3/4"
3/4"
NOTCH 1/2" ON 45° ANGLE
NOTCH 1"
SLIT 1"
1/2" S-SLIP ALLOWANCE
CROSS BRAKE UP
BEND DOWN 30°
NOTCH 1/2" ON 45° ANGLE
SLIT 1"
NOTCH 1"
1" PITTSBURG ALLOWANCE
BEND DOWN 60°
BEND UP 180°
BEND DOWN 60°
BOTTOM PATTERN (PIECE 4)
530-3931

Figure CRE Ans–2. Patterns for a transition.

b. The square shaft attachment plate can be riveted to either end of the damper blade. (5-16; Fig. 46)

c. The square shaft of the damper blade is inserted correctly if the control handle is at the open position when the damper is parallel to the top and bottom of the duct. (5-16; Fig. 44)

d. One or both of the attachment plates have been installed below the centerline of the two sides of the duct. (5-16; Fig. 44)

8. The louver damper is located at the outside air intake in the return air system. The louver damper is hand operated with a control quadrant. (5-19; FO 2)

9. (1) The linkage may be too tight and should be lubricated or repaired and (2) the

louver damper assembly may be installed upside down, causing the blades to swing down when the motor is off. This could be corrected by removing the assembly and replacing it in the correct position. (5-21; Fig. 47)

10. The heads of the screws will be visible on the inside of the flange because the flange is inserted into the duct and then fastened. (5-23; Fig. 48)
11. The flange of the damper assembly is not completely inserted into the outlet on the side that is ¼-inch low. (5-23; Fig. 48)
12. The blade frame of the register should be 13¾ x 15¾ inches, although it is called a 14 x 16-inch frame. (5-26)
13. Hold the register up to the duct and use the face frame as a template to mark the locations of each hole. (5-26; Fig. 49)
14. There would be five door grilles and eight wall grilles. The door grilles are located in rooms 1, 8, 7, and 13, and in the latrine. The wall grilles are located in rooms 2, 9, 3, 10, 5, 11, 6, and 12. (5-27; FO 1)
15. The latrine has a larger return air grille because the room is larger and the supply outlet is larger. (5-27; FO 1)

CHAPTER 3

Section 6

1. On a working drawing such as the plan view shown on foldout 1, the visible dimension is listed first, such as the width of trunk line A (24 inches). A second method to determine or verify which dimension is the width is to take a rule (or architect's scale) and measure the width in the plan view. (6-5; FO 1; and Vol. 1)
2. 4′ of 20″ x 10″ rectangular duct
   12″ for a 20″ x 10″ to 16″ x 10″ transition
   16′6″ of 16″ x 10″ rectangular duct
   12″ for a 16″ x 10″ to 14″ x 8″ transition
   8′6″ of 14″ x 8″ rectangular duct
   12″ for a 14″ x 8″ to 12″ x 8″ transition
   10′ of 12″ x 8″ rectangular duct
   (6-7, 6; FO 1)
3. The width of the trunk line decreases 2 inches at each transition; however, only one-half of the reduction is on the side that has branch lines to rooms 3, 2, and 1. (6-9; FO 1)
4. If trunk line B is changed to 20″ x 10″, 18″ x 10″, 16″ x 8″, and 14″ x 8″, the round duct branch lines will also be changed. The duct in room 5 will become 7′5″, the duct in room 12 will become 7′6″, and the duct in room 7 will become 7′7″. (6-9; FO 1)
5. Because the Pittsburg lock seam is used for corner seams, and the round ducts do not have corners. (6-15, 16; 2-5; FO 1)
6. *a.* 3. (6-19; 2-26; Fig. 17; FO 1)
   b. 1. (6-19; 7-9; Fig. 67)
   c. 1. (6-19; 7-9; Fig. 67)
   d. 2. (6-16; FO 1)
   e. 4. (6-17; FO 1)
7. Standing S-and-drive slips can be used to connect the 12″ x 8″ joints when the joints are made on centers greater than 35 inches but less than 7 feet 11 inches. (6-20; Figs. 28, 57, 60)
8. The return air duct (return air and outside air plenum) will have three joint connections which use three standing S-slips and three drive slips. (6-20, 12; Fig. 62; FO 2)
9. All four sides should be stiffened by cross braking. (6-23; Fig. 28; FO 1)
10. Because air-conditionng ducts should be protected from rust. Black iron does not have a protective coating like galvanized sheet iron. (6-25; FO 1)
11. Galvanized sheet iron should be used because the ducts, even if altered and installed below the ceiling, will continue to be exposed to condensation and corrosion. (6-25; FO 1)
12. 26-gage galvanzied sheet iron is recommended for ducts up to 12 inches wide. (6-26; Fig. 28; FO 1)
13. *a.* 24 gage.
    b. (1) 24 gage.
    (2) 24 gage.
    (3) 24 gage.
    (4) 26 gage.
    c. 24 gage.
    d. 26 gage.
    (6-26; Fig. 28; FO 1)
14. The 36″ x 97¼″ pattern must be cut from a 10-foot sheet because an 8-foot sheet is only 96 inches long. (6-31; Fig. 52)
15. According to figures 54 and 55, four sheets 3′ x 10′ are needed to make trunk line A and the plenum. (6-31–39; Figs. 53–55)
16. *a.* The largest piece of leftover material in sheet 1 of figure 55 is 2½″ x 11½″, which is large enough to make one 2¼″ x 10″ drive slip for the 12″ x 8″ section of trunk lines B and C. (Figs. 55, 26; FO 1)
    b. One 5½″ x 7¾″ standing S-slip can be made from the leftover material in figure 55. (Figs. 55, 23; FO 1)
    c. The drive slips for the 18″ x 10″ and 16″ x 10″ sections of trunk line B will

be 2¼" x 12" each. According to figure 55, ten drive slips of this size can be made as follows:
2 each from sheet 2
4 each from sheet 3
4 each from sheet 4
(Figs. 55, 26; FO 1)

17. The perimeter of trunk line A is 76 inches. The metal pieces are joined with Pittsburg lock seams which require 1¼-inch seam allowance, making a total of 77¼ inches. The cloth has a 1-inch lap seam joined by sewing, requiring 77 inches of asbestos cloth. (6-39, 34; Fig. 56)
18. 3 sheets 3′ x 10′
3 sheets 3′ x 8′
1 sheet 4′ x 10′
(6-24–47; Figs. 58, 59)
19. A 3′ x 10′ sheet or other smaller combinations of sizes are too small. (6-45; Fig. 59)
20. Transition 2, 56" x 12"
Transition 8, 52" x 12"
Transition 12, 44" x 15"
(6-46, 37; Figs. 57, 58, 59)
21. Sheet 1, 9½" x 36"
Sheet 2, 13½" x 36"
Sheet 3, ¾" x 36"
Sheet 4, 6" x 36"
Sheet 5, 6" x 41¼"
6¾" x 10"
Sheet 6, 5½" x 26"
7½" x 26"
3" x 16"
4" x 16"
12" x 36"
Sheet 7, 23¼" x 36"
9" x 10"
3" x 59"
15½" x 14"
(6-47; Fig. 59)
22. *a.* 36" x 61¼". (6-48; Fig. 60)
b. Yes. (Fig. 60)
c. Joints 14 and 15 in figure 60 are on 4′8" centers because each has a stretchout small enough to be economically made from a 4′ x 10′ sheet. (6-48; Fig. 60)
d. Joint 1, 36" x 61¼"
Joint 2 (top and bottom), 13" x 22"
Joint 2 (sides), 10½" x 13"
Joint 3, 36" x 53¼"
Joint 4, 24" x 53¼"
(Fig. 60)
e. 3 sheets 3′ x 10′
1 sheet 3′ x 8′
(Fig. 60)
f. Standing S-slips
4 each 5½" x 19¾"
14 each 5½" x 15¾"
Drive slips
18 each 2¼" x 12"
(Fig. 60)
23. Only the latrine in figure 60 has a round duct joint longer than 12 inches but shorter than 34½". (6-50; Figs. 57, 60)
24. *a.* The 34½-inch joints in the 8-inch round ducts will each require pieces of material 26⅛" x 36".
b. Five joints, 34½-inches long and 8-inches in diameter, are needed.
c. Four pieces 26⅛" x 36" can be made from one 3′ x 10′ sheet; therefore, 1½ sheets will be needed to make the five 34½-inch joints and one 25½-inch joint. (6-51, 50; Figs. 57, 60)
25. *a.* The 6-inch duct will require a 12½-inch drop joint. (6-54; Fig. 60)
b. The 8-inch duct will require a 9½-inch drop joint. (6-54; Figs. 61, 57, 60)
26. The largest rectangle that can be made from the leftover material is 29⅞" x 36". (6-55, 49–54; Fig. 61)
27. 1 each 18" x 36" multiblade damper
3 each 8" adjustable dampers
12 each 6" adjustable dampers
(6-61; FOs 1, 2)
28. Trunk line A will require four pieces of insulation as follows:
2 pieces 48" x 82"
1 piece 14" x 82"
1 piece 18" x 28"
The two cutouts for joints 7 and 8 will be 12" x 20" and 12" x 18". (6-63; Fig. 53)
29. The branch line in room 2 will require three pieces of foil-backed insulation as follows:
6′10" x 24" for the straight section
13½" x 24" for the elbow
10⅜" x 24" for the drop joint
(6-63, 9; Figs. 60, 61)

Section 7

1. *a.* The parallel line layout method is used because the sides of the rectangular-shaped pattern are parallel (or perpendicular) to each other. (7-2, 3; Fig. 63; and Vol. 1)
b. The element lines are 35 inches long because joints 4 and 5 are 35 inches long, center to center. (7-4; Figs. 53, 63)
c. The element lines are spaced 14 and 24 inches apart because the duct is 24 inches wide and 14 inches high. (7-4; Figs. 53, 63)
d. The stretchout of the pattern in figure 63 is 76" x 35" which will require a sheet of metal 77¼" x 36" because of the 1¼-

inch seam allowance and the ½-inch S-and-drive slip allowances. (7-4, 17; Fig. 63)

e. The notches at the corners and at the element lines of the pattern in figure 63 are necessary so that the sheet metal can be bent along the brake lines to allow easier assembly of seams, easier assembly of joint connections, and easier installation of the drive slips. (7-21; Fig. 63)

2. *a*. Parallel-line layout method. (7-3, 4; Fig. 57)
   b. Five element lines. (7-4; Figs. 57, 63)
   c. The pattern, including seam and joint allowances, will be 57¼" x 36". (7-3, 4; Figs 57, 63)
   d. All four sides will be cross broken. (7-28; Figs. 57, 63)
3. See figure CRE Ans–3. (7-3, 4, 21, 28; Figs. 60, 63, CRE Ans–3; and Vol. 1)

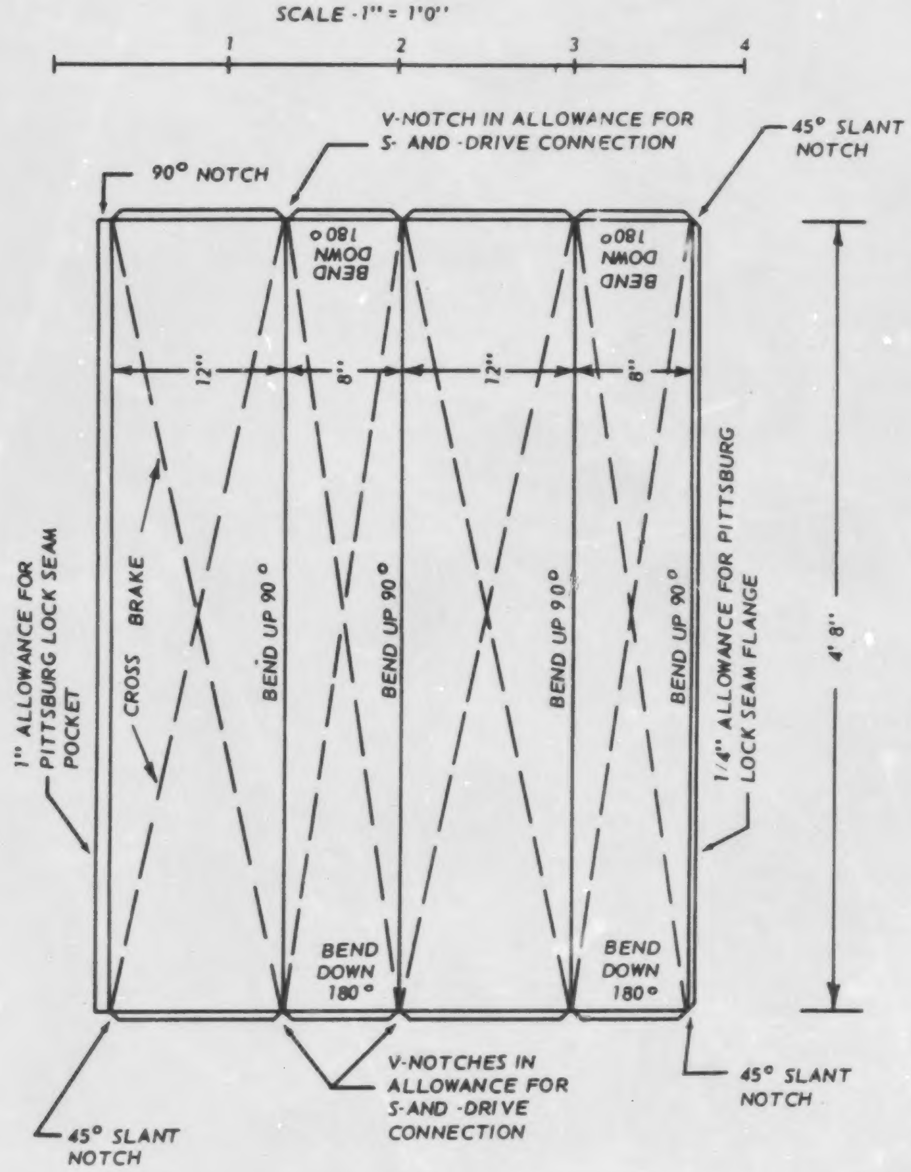

SCALE - 1" = 1'0"
1
2
3
4
V-NOTCH IN ALLOWANCE FOR S- AND -DRIVE CONNECTION
90° NOTCH
45° SLANT NOTCH
BEND DOWN 180°
BEND DOWN 180°
12"
8"
12"
8"
1" ALLOWANCE FOR PITTSBURG LOCK SEAM POCKET
CROSS BRAKE
BEND UP 90°
BEND UP 90°
BEND UP 90°
BEND UP 90°
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM FLANGE
4' 8"
BEND DOWN 180°
BEND DOWN 180°
V-NOTCHES IN ALLOWANCE FOR S-AND -DRIVE CONNECTION
45° SLANT NOTCH
45° SLANT NOTCH

Figure CRE Ans–3. Pattern for joint 15 of trunk line C.

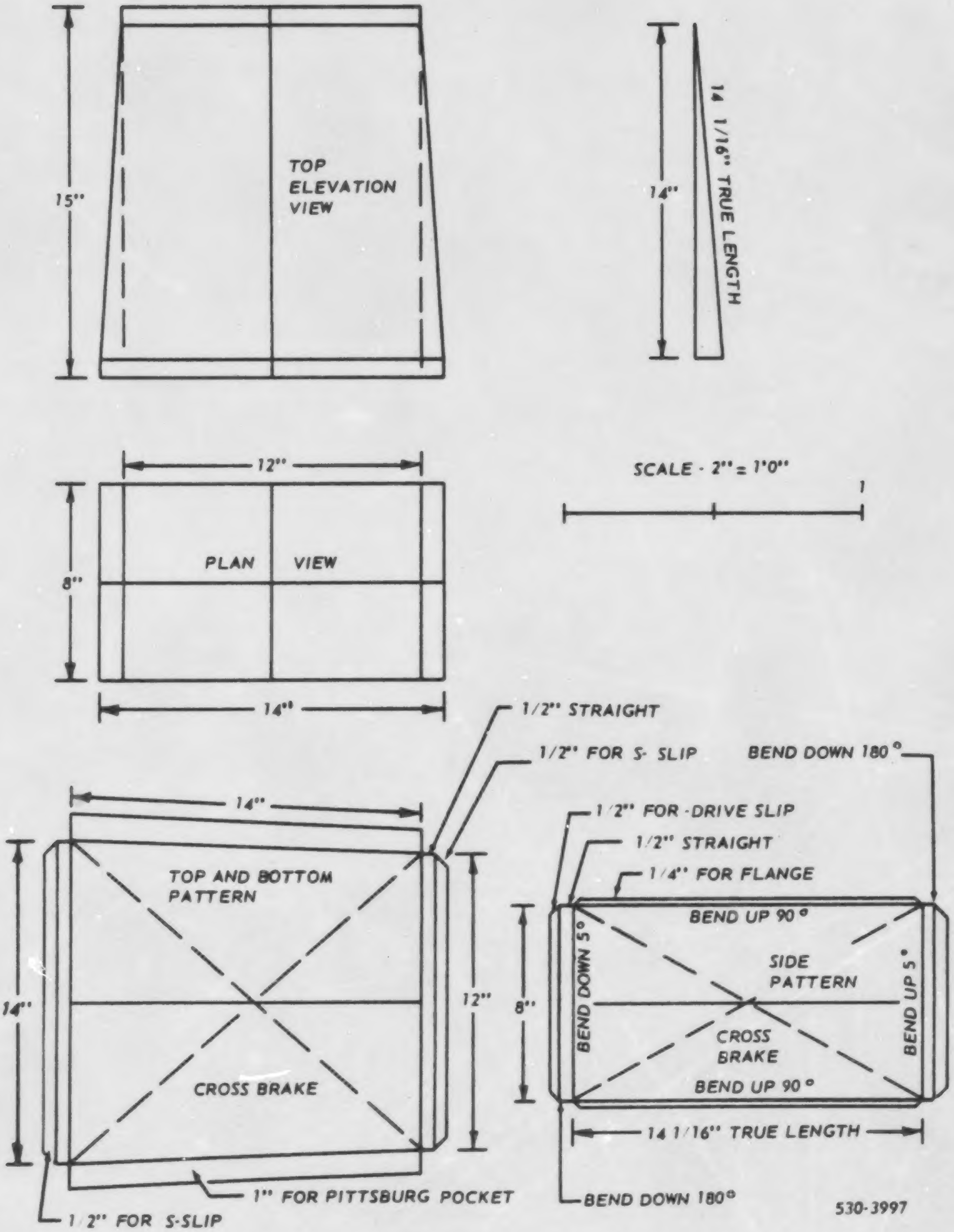

15"
TOP
ELEVATION
VIEW
14"
14 1/16" TRUE LENGTH
12"
PLAN VIEW
8"
14"
SCALE - 2" = 1'0"
1
1/2" STRAIGHT
1/2" FOR S- SLIP
BEND DOWN 180°
14"
TOP AND BOTTOM
PATTERN
CROSS BRAKE
14"
12"
1" FOR PITTSBURG POCKET
1/2" FOR S-SLIP
1/2" FOR -DRIVE SLIP
1/2" STRAIGHT
1/4" FOR FLANGE
BEND UP 90°
SIDE
PATTERN
BEND DOWN 5°
BEND UP 5°
CROSS
BRAKE
BEND UP 90°
8"
14 1/16" TRUE LENGTH
BEND DOWN 180°
530-3997

Figure CRE Ans–4. Patterns for joint 12 of trunk line B and joint 13 of trunk line C.

4. The pattern in figure 64 is for a round duct duct joint with a grooved seam. The 180° bends for the seam must be turned opposite sides so the seam will fit together when the joint is assembled. (7-5. 31; 2-9; Figs. 64. 12)
5. The piece should be 13½" x 26⅛". The length of the joint is 12" + 1½" (allowance for the slip joint), and the stretchout is 25⅛" + 1" (allowance for the grooved seam). (7-5; 6-50; Figs. 60. 64)
6. *a.* The triangulation method is used for transitions because they have sides that are not parallel nor do they meet at a common point. The true length of the slanting sides must be determined. (7-6; Fig. 65; and Vol. 1)
   b. The pattern stretchouts are the true heights of the slanting sides and are 1/16 inch longer than in the plan and elevation views. (7-6, 6-46; Fig. 65)
   c. The ½-inch "straight" is used to return the slanting sides parallel with the duct so that the S-and-drive slips will fit properly. A similar example is shown in figure 31 for S-slips. (7-6; Figs. 65. 31)
   d. The transition patterns can be easily cut from sheet 6 (Fig. 59) with squaring shears. (7-19; Figs. 59. 65)
   e. Notches for each corner of the top and bottom patterns include a 90° square notch for the 1-inch Pittsburg allowance. a 90° square notch for the ½-inch "straight" allowance. and a 45° slant notch for the S-slip connection allowance. (7-21. 23; Fig. 65)
   f. This transition is made in four pieces and does not have corner bends because each corner has a Pittsburg lock seam. (7-32. 27; Fig. 65)
7. See figure CRE Ans–4. (7-6–8. 4. 23; Figs. 57. 65. CRE Ans–4; and Vol. 1)
8. *a.* Without allowances. the pattern should be 12" x 8". (7-9; Figs. 60. 66)
   b. With allowances included. the pattern should be 16" x 12". (7-9; Figs. 60. 66)
   c. The metal should be turned over and bent up on the cross brake lines. (7-9. 28. 34; Figs. 60. 66)
9. See figure CRE Ans–5. (7-9. 24. 34; Figs. 60. 66. CRE Ans–5)
10. *a.* The heel radius for the 8-inch elbow is 16 inches. (7-10; Figs. 60. 61. 68; and Vol. 1)
    b. Gores I and V are half-gores. Gores II. III. and IV are whole gores. (7-10; Fig. 68; and Vol. 1)

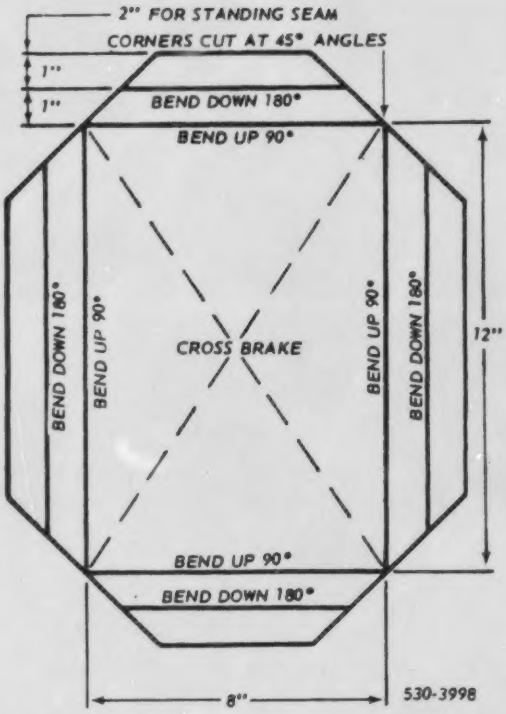


Figure CRE Ans–5. End cover pattern for joint 15 of trunk line C.

    c. The working line for the 8-inch elbow stretchout is 25⅛ inches long. (7-11; Fig. 68; and Vol. 1)
    d. The length of the element lines on the stretchout is determined by the length of the element lines from the plan view as they pass through the miter lines of gore I. (7-11; Fig. 68)
    e. The allowance for the slip joint will be on gore I for the 8-inch elbow the same as for the 6-inch elbow. (7-20; Figs. 68. 70)
11. See figure CRE Ans–6. (7-10. 11. 12. 25; Figs. 57. 68. CRE Ans–6; and Vol. 1)
12. See figure CRE Ans–7. (7-10–12. 20. 25; Figs. 70. CRE Ans–6. CRE Ans–7)
13. Straight snips are not needed. In this job. straight snips are used principally for notching. The round duct joints do not need notching. Also. because of the extensive number of cuts to be made. squaring shears will be used instead of hand-operated straight snips. (7-31. 22; FO 1; and Vol. 2)
14. The ridges will be on the outside of the transition. (7-32. 2; Fig. 65)
15. The Pittsburg lock forming machine. slip

436

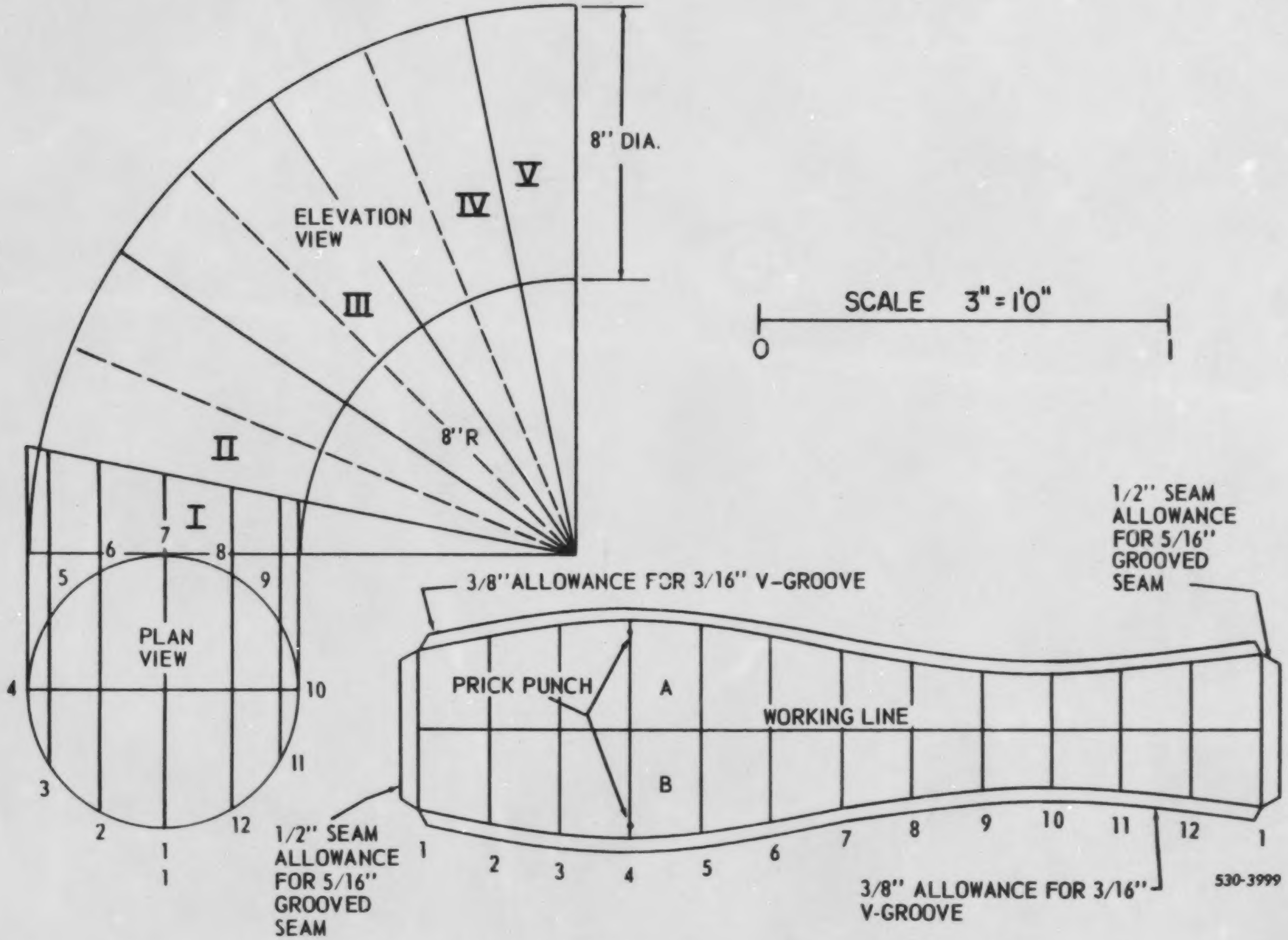

8" DIA.
V
IV
ELEVATION VIEW
III
8"R
II
I
SCALE 3" = 1'0"
0
1
6
7
8
5
9
PLAN VIEW
4
10
11
3
2
1
12
1
3/8" ALLOWANCE FOR 3/16" V-GROOVE
1/2" SEAM ALLOWANCE FOR 5/16" GROOVED SEAM
PRICK PUNCH
A
WORKING LINE
B
1/2" SEAM ALLOWANCE FOR 5/16" GROOVED SEAM
1
2
3
4
5
6
7
8
9
10
11
12
1
3/8" ALLOWANCE FOR 3/16" V-GROOVE
530-3999

Figure CRE Ans-6. Pattern development for 8-inch elbow gores.

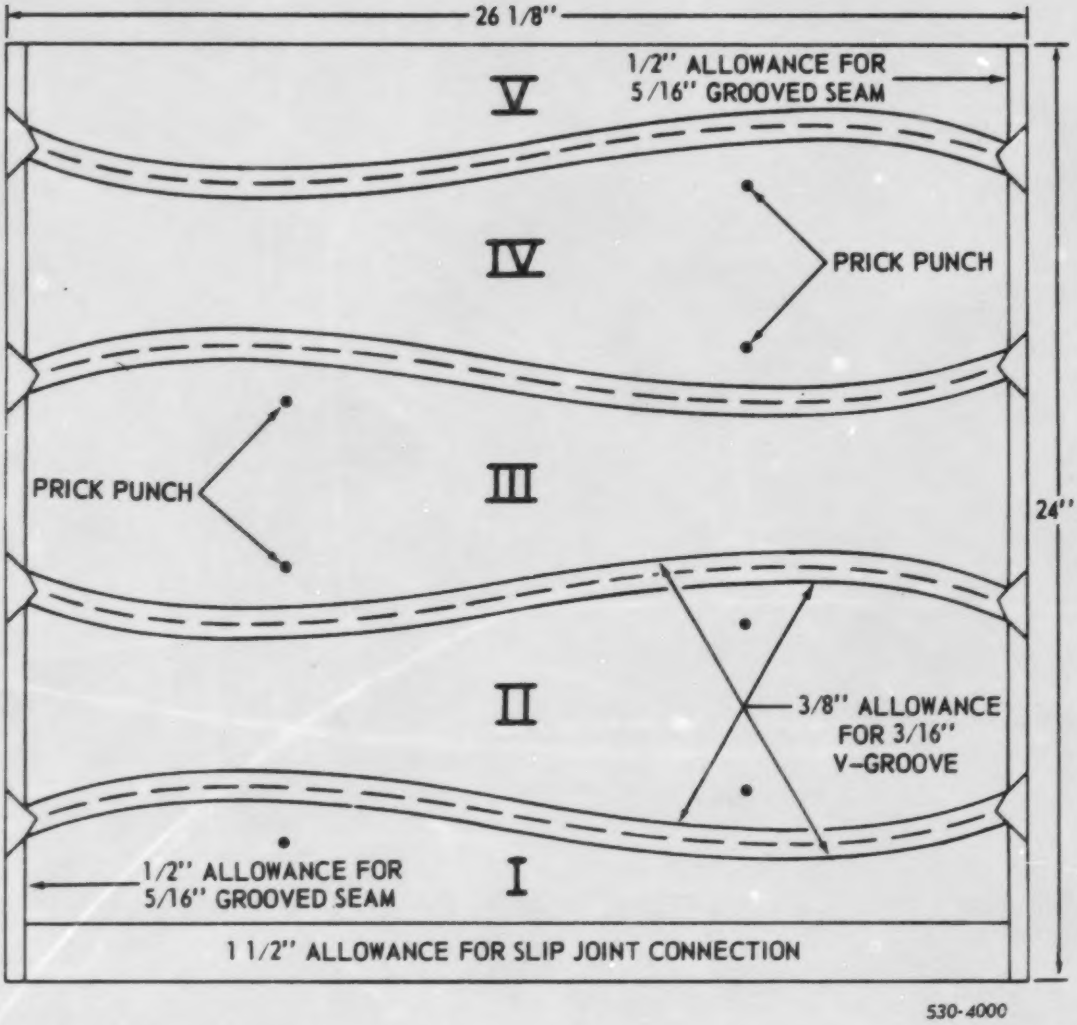

26 1/8"
1/2" ALLOWANCE FOR
5/16" GROOVED SEAM
V
IV
PRICK PUNCH
PRICK PUNCH
III
24"
II
3/8" ALLOWANCE
FOR 3/16"
V-GROOVE
1/2" ALLOWANCE FOR
5/16" GROOVED SEAM
I
1 1/2" ALLOWANCE FOR SLIP JOINT CONNECTION
530-4000

Figure CRE Ans–7. Patterns for 8-inch elbow gores.

roll forming machine, and elbow edging machine. (7-35; Fig. 73)

16. The 180° bends for the grooved seams on each end of the five gores will be on opposite sides. For example, if one end is turned up, the other end must be turned down, as shown in figure 12. (7-35, 31; 2-9; Figs. 12, 64, 70)
17. Hand groover; slip roll; elbow edging; 73; spread; slip; tinner's setting; bench; align; crimping; beading. (7-35, 31; 2-9; Figs. 73, 70, 35, 11)
18. With the tabs bent 90° at each end, the turn vanes should be exactly 14 inches long so that they will fit into joint 6 which is 14 inches high. (7-36, 14; Fig. 69)
19. More turn vanes are installed on the trunk line C side because the diagonal installation line is longer on the trunk line C side. (7-36, 14; Fig. 69)
20. The two 14-inch allowances are bent 180° because the sides of the flexible connector are 14 inches high and have drive slip connections. As shown in view B of figure 74, the bend instructions should be up because the double seam is also bent up. (7-37; Fig. 74)
21. The double seam should be formed before making the 90° corner bends. (7-37; Fig. 74)

Section 8

1. *a.* 22 inches from each wall of the hallway. (8-3; FO 1)
   b. 22 inches from each wall of the hallway. (8-3; FO 1)
   c. 9 feet 9 inches. (8-4; FO 2)
2. *a.* 8 feet 2 inches.
   b. 8 feet 2 inches.
   c. 8 feet 2 inches.
   (8-3; 6-9; FO 1)
3. 9 feet 9 inches. (8-4; FOs 1, 2)
4. Two strips, 1 inch wide and 35 inches long. (8-5; Fig. 75)
5. Four double-thickness hangers, 1 inch wide and 36 inches long. (8-5; Figs. 59, 75; FO 1)
6. Nails, sheet metal screws, hammer, screwdriver, Whitney hand punch, portable drill, electrical extension cord, and twist drills. (8-5, 6; Fig. 75)
7. *a.* 28 S-slips. (8-6; Fig. 57)
   b. 28 drive slips. (8-6; Fig. 57)
   c. Trunk line B will require 18 hangers. (8-6, 10; Fig. 57)
   d. The branch lines from trunk line B will require 14 hangers. (8-6, 12; Fig. 57)
8. *a.* Joint 2 to the plenum, joint 7 to 6, and joint 8 to 6. (8-7; Fig. 53)
   b. Joint 2 to 3, 3 to 4, 4 to 5, and 5 to 6. (8-7; Fig. 53)
   c. Joints 3, 4, 5, and 6. (8-9, 10; Fig. 53)
   d. 20 inches. (8-10; Fig. 53, FO 2)
   e. The point of intersection of each cross brake line. (8-10)
9. *a.* None. (8-11, 8; Fig. 57)
   b. Joints 1 through 14. (8-11, 10; Fig. 57)
   c. Joints 3, 4, 5, 7, 9, 11, 12, 13, and 14. (8-10; Fig. 57)
   d. 20 inches for both. (8-10; Fig. 57, FO 2)
   e. By bending the tabs of the dovetail seams. (8-12; Fig. 57)
10. *a.* Five slip joints. In figure 61, joint 2 slips into joint 1, 3 into 2, 4 into 3, 5 into 4, and 6 into 5. (8-12; Figs. 57, 61)
    b. One near the slip joint between joints 2 and 3 and one near the slip joint between joints 3 and 4. (8-12; Fig. 61)
    c. 98 inches. (8-12; Fig. 61)
11. *a.* The allowance to make the folded seam is 6 inches. (8-15, 18; 6-63)
    b. No allowance is necessary because the edges have a foil tab that makes the lap joint. (8-16, 18; 6-62)
12. Cuts; wrap; 62; (56 plus 6); 58; 50; 116; 2, 8, 12; slit; hangers; 6; elbow; drop; elbow; lap; wire. (8-14–18; 6-63, 65; Fig. 57)
13. The return air duct in foldout 2 fits inside a wood frame; therefore, the screws through the register face frame attach to the wood frame, and the 90° flanges on the duct are not needed. (8-20; Fig. 49; FO 2)
14. *a.* The hole should be 12¼" x 8¼" for a ⅛-inch clearance on each side of the grille. (8-22; 5-27; FO 1)
    b. The bottom line will be 6 inches from the bottom of the door. The top line will be 14¼ inches from the bottom of the door. The two vertical lines for the sides of the hole will be 12¼ inches apart and located 8⅞ inches for the sides of the door. (8-21)
    c. Aviation snips should be selected to cut out the retangular-shaped opening after a chisel is used to cut a slit. (8-22; and Vol. 2)
15. Because the volume control frame (ring) is flanged and is designed to fit inside the duct; therefore, no flange is needed in the duct (view A of fig. 48). (8-23; 5-22; Fig. 48)
16. Make sure the damper ring is installed flush with the ceiling when the holes are located. (8-23; Fig. 48)

Section 9

1. The disc should be 7 inches in diameter so that a ¼-inch lap seam can be made. (9-2; and Ch. 1)
2. *a.* The disc should be 4½ inches in diameter.
   b. The location of the centerline should be ⅜ inch from the edge of the disc.
   c. Tinner's rivets 2½-pound size should be used, and the holes should *not* be spaced over 2½ inches apart. (9-2; 1-5; and Vol. 2)
3. *a.* You must know the dimensions of the old connector (height, width, and length) type of fabric, and type and gage of metal. (9-5)
   b. Four drive slips and four S-slips are needed for the replacement flexible connection. (9-5; Fig. 56)
4. *a.* Straighten out the drive slips and remove them from each end of the flexible connection, pull the metal pieces out of the S-slips, and remove the whole assembly. (9-8; Figs. 27, 56)
   b. Insert the metal pieces of the new connection into the pockets of the S-slips, install the drive slips, and bend the ends

of the drive slips to lock the joint. (9-9; Figs. 27, 56)

5. *a.* Joint 12 is 42 inches long (center to center).
   b. Joint 12 is 60 inches wide (center to center).
   c. Joint 12 is 12 inches high. (9-11; Figs. 77)
   d. The point of intersection of the centerlines is 36 inches from the standing S-slip between joints 11 and 12. (9-11; Fig. 77)
6. *a.* The top (or bottom) pattern will require a piece of metal 43″ x 61″. (9-12; Figs. 77, 78)
   b. Each side and heel pattern will require a piece of metal 14″ x 61″. (9-13; Figs. 78)
   c. Each side and throat pattern will require a piece of metal 14″ x 37″. (9-13, 12; Figs. 78)
7. Pattern A (9-13, 12; Fig. 78)
8. Patterns B and C. (9-13, 12; Fig. 78; and Vol. 2)
9. Patterns B and C. (9-15; Fig. 78)
10. The 24-inch radius will be rolled up. (9-15; Fig. 78)
11. The pocket of the Pittsburg seam will be on on the reverse side. (9-15; Fig. 78)
12. Four joint connections must be disconnected to remove joint 12. (9-16; Fig. 77)
13. Remove the registers from joints 13, 14, and 15; make temporary supports for joint 12; disconnect the hangers from joint 13; remove fasteners that attach joints 13, 14, and 15 to the walls; remove drive slips from joints 13, 14, and 15; remove joints 12, 14, and 15; remove drive slips between joints 12 and 11; and remove joint 12 by slipping it out of the S-slips. (9-16; Fig. 77)
14. Eight drive slips. (9-17, 15; Fig. 77)
15. The reverse order of the removal steps will be necessary; however, new drive slips should be used. (9-17, 16; Fig. 77)
16. Install the S-slips on joints 11 and 13 in the conventional manner, and slide joint 12 sideways into the S-slip pockets of joint 11. Continue to slide joint 12 until the allowance at the other end enters the S-slip pockets of joint 13. Continue to slide joint 12 until both ends are in alignment with the connections. The last step is to install the drive slips and bend the ends to lock the joints. (9-17, 16; Figs. 77, 27)

CHAPTER 4

Section 10

1. Nearly as good. (10-2; Fig. 79)
2. So the wind can reach the stack from any direction. (10-2)

Section 11

1. The adjustable "L" offset would be better suited because it can be adjusted for different offset positions. (11-5; Fig. 81)
2. The blade is in a downdraft position. (11-7; Fig. 82)
3. The draft diverter should be parallel to the floor. (11-8)
4. Piece B should be 10 inches long. (11-10; Fig. 84)
5. *a.* 8. (11-10; 2-5; Fig. 84)
   b. 1, 2, 4, 6, 9, and 10. (11-10; 12-20; 7-31; Fig. 84)
   c. 1, 3, 5, and 7. (11-10; Fig. 84; and Vol. 2)
6. "E" is not draft diverting or rainproof because it is open all around the airspace. (11-14; Fig. 86)

Section 12

1. The upper stack, collar, and vent cap would probably need replacing more often than the other components. (12-1; Fig. 80)
2. *a.* Visual inspection of the complete assembly. (12-1)
   b. The pitch of the roof and the dimensions of the stack joints, roof jack, collar, and vent cap. (12-1, 3; Fig. 80)
   c. The gage of the metal can be determined from the old stack assembly or from the working drawing. (12-2)
3. The triangulation layout method should be used. (12-5; 13-5; and Vol. 1)
4. The radial line layout method should be used. (12-5; Figs. CRE-3, 80; and Vol. 1)
5. *a.* 3.
   b. 4.
   c. 2.
   d. 5.
   e. 8.
   f. 7.
   (12-5; Fig. CRE-3; and Vol. 1)
6. Because it is a weatherproof and draftproof vent cap. (12-7, 4; Fig. 80 and Vol. 1)
7. The cutout arc will be 2⅜ inches long. (12-8; Fig. 89, and Vol. 1)
8. *a.* 10. (12-12, 18; Fig. 90; Vol. 2)
   b. 3. (12-12; Fig. 90; and Vol. 2)

   c. 2 and 3. (12-12; Fig. 90; and Vol. 2)
   d. 1. (12-13, 22; Fig. 90 and Vol. 2)
   e. 7. (12-12; Fig. 90; and Vol. 2)
   f. 8. (12-28; Fig. 90; and Vol. 2)
   g. 6. (12-23; Fig. 90; and Vol. 2)
   h. 5. (12-26; Fig. 90; and Vol. 2)

9. *a.* The hole should be 6$\frac{1}{16}$ inches in a diameter. (12-12, 11-3, 5, Fig. 90)
   b. The ring pattern will have an outside diameter of 10$\frac{1}{16}$ inches. (12-12; Fig. 90)
10. Down; up; up; down; down; down. (12-15; Fig. 91)
11. The slip roll forming machine. (12-19; Fig. CRE–3)
12. The grooved seams on the roof jack in figure CRE–3 should be soldered about 4 inches on the side. (12-24; Fig. CRE–3)
13. The tabs are bent in the same direction (as shown in fig. 17). If they are bent in opposite directions, the base will not be held between the tabs. (12-24; Fig. 17)
14. The plumb bob should be used to locate the centers of the holes. (12-27; Fig. 80)
15. The center location of the storm collar is not aligned properly with the plumb bob. To correct this mistake, an adjustable offset "L" can be used. (12-27; Figs. 80, 81)

Section 13

1. Ventilator "C" because it has a fan and motor to draw air out of the building. (13-1; Fig. 92)
2. The triangulation layout method should be used. (13-5; Figs. 92, 93)
3. The distance from the base line to point CD would be 1 inch. (13-5; Fig. 93, and Vol. 1)
4. Line BC should be 90° to base line AB. (13-8; Fig. 94)
5. The second pattern should be turned over to run through the Pittsburg lock forming machine so that the pockets will be turned down when the 22½° lines are bent up. (13-8; Fig. 94)
6. No. (13-9; Fig. 94; and Vol. 2)
7. The corner clips will be 4¾" x 4¾" (for ⅜-inch flat laps), and 2-pound tinner's rivets should be used. (13-9; 1-4, 5; Fig. 94)
8. Asphalt roofing cement or hot roofing tar should be used around the flashing. (13-13; Fig. 92)
9. The hole for the draft ventilator should be 12" x 12". (13-13, 4; Fig. 94)

CHAPTER 5

Section 14

1. *a.* 8 feet.
   b. 30 inches.
   c. 12 inches.
   d. 25½ inches.
   e. 44¾ inches.
   (14-5–8; Figs. 97, 98)
2. *a.* 45½ inches.
   b. 47¼ inches.
   c. 45½ inches.
   d. 54 inches.
   (14-5–8; Figs. 97, 98)
3. 10$\frac{15}{16}$ inches. (14-9; Fig. 98)
4. 36$\frac{7}{16}$" x 96". (14-9, 11; Fig. 98)
5. Up; down; down, down; down; up. (14-13; Fig. 98)
6. On the inside. (14-13; Fig. 98)
7. The flanges of the front and back pieces will fit inside the pockets of the side pieces. (14-15; Fig. 98)
8. The four corners of the collar and the four corners of the skirt are butt joints. (14-15; Fig. 98)
9. Each standing seam will have five Monel rivets. (14-15; Figs. 97, 98)
10. A total of 62 Monel rivets are used to assemble the hood shown in figure 96. (14-15–19; Figs. 96, 99)
11. The adhesive paper protects the surface of the stainless steel from scratches throughout the fabrication and installation period. (14-21, 3)
12. The filter is 12" x 20". (14-21; Fig. 96)

Section 15

1. The metal for the replacement panel will be 37½ inches long (1½ inches for the flange) and 30 inches wide. (15-8; Fig. 100)
2. The brass round stock for the splice will be $\frac{7}{8}$ inch in diameter and 6 inches long. (15-12, 4; Fig. 102)
3. The distance between the centers of the holes is determined by the spacing (center to center) of the tray slide rails. (15-14; Fig. 103)
4. 21" x 35". (15-15; Fig. 104)
5. *a.* 30°.
   b. 15°.
   c. 45°.
   (15-16, 17; Fig. 104)
6. *a.* The horizontal centerlines are 3 and 9 inches from the top.

b. The vertical centerlines are 3, 10, and 17 inches from the left side.
(15-16; Fig. 104)

7. Remove the grinding wheel and replace it with a grinding wheel that is used only for stainless steel. (15-22)
8. A number 7 finish has a brighter luster than number 4 or 5, because it is made with a finer abrasive on the buffing wheel. (15-25)

Section 16

1. *a* 1½ inches.
   b 1¼ inches.
   (16-2; Figs. 105, 106)
2. *a*. 2 inches.
   b. 6 inches.
   c. 70 inches.
   (16-2; Figs. 105, 106)
3. Set the fingers to make a bend 32 inches wide. (16-4; Fig. 106; and Vol. 2)
4. The two back corners that connect the back piece and side pieces are assembled with Pittsburg lock seams. (16-7; Figs. 105, 106)
5. The top front piece should be riveted to the top piece. (16-7; Fig. 105)
6. To remove the rivets, drill from the outside because the factory made heads, in this example, are on the outside of the shower stall. (16-11; Fig. 105)
7. The bottom end will give more trouble because the rivets and seams are soldered. (16-11; Fig. 105)

Section 17

1. Grooved seams and butt joints with cap strips. (17-3, 4)
2. You should use 4′ x 8′ sheets. (17-4)
3. The fire door will be covered with 14 pieces of formed sheet metal. (17-5, 6; Fig. 107)
4. Squaring shears, straight snips, cornice brake and hand seamer. (17-6; Figs. 108, 109; and Vol. 2)
5. The long bends must be made first; therefore, the pieces cannot be placed in the cornice brake without damaging their shape. (17-6; Fig. 108)
6. A flat lap seam. (17-17; 1-3)
7. *a*. Open the grooved seams (to the standing seam position) along the sides and both ends. Work the side piece free from the other piece. All nails that interfere with the removal should be taken out.
   b. Like C in figure 108.
   c. 10″ x 6′8″.
   (17-18, 8; Figs. 107, 108)

Section 18

1. Hold the weatherstrip up to and level with the window facing. Use the weatherstrip as a template and mark the hole locations with a pencil. (18-3; Fig. 110)
2. Screwdrivers, adjustable wrench, masonry drill, portable electric drill, and calking gun. (18-2–4; Fig. 110)

Section 19

1. A riveted lap seam (flat or corner) will have the rivets down the middle of the lap seam (1 inch in B of fig. 113). Therefore, this seam is a ½-inch riveted corner lap seam and requires 1 inch of allowance. (19-4; 1-4; Fig. 113)
2. The patterns for the sides (identified as B in fig. 113) and the pattern for the weatherstrip (E) will require straight snips. (19-8; Fig. 113)
3. The corner lap seam bends on each end of the side trim pieces. (19-10; Fig. 113)
4. The rivets should be 0.602 inch long (approximately 19/32 inch). (19-11; Fig. 112; and Vol. 2)
5. The canopy is attached to the wall with ¼-inch lag screws and number 10 sheet metal screws, each with expandable sleeves. (19-12, 13; Fig. 112)
6. It would be better to remove the canopy because of the difficulty in reaching the rivets to be removed and replaced. The canopy can be removed without taking off the weatherstrip or angle brace. (19-19, 20; Fig. 112)

CHAPTER 6

Section 20

1. To prevent corrosion caused by galvanic action between dissimilar metals. (20-3; and Vol. 1)
2. Cadmium-plated sheet metal screws. (20-3, 7)
3. Copper sheets will last longer because copper sheets have a greater resistance to corrosion. (20-5; and Vol. 1)
4. Copper sheets should be used. (20-5)
5. The standing seam, because it is not soldered and is not recommended for roofs with a pitch less than 3 to 12. (20-10, 12)

6. Roofing grooved (flat) seams. (20-10, 12, 15)
7. The common gage size double seamer should be used. (20-19
8. The wide gage size double seamer should be used. (20-19; Fig. 116)
9. A corrugated aluminum roof is being installed. (20-24, 6; Fig. 124)
10. If the prevailing wind is from the opposite direction, sheet D should be installed first. (20-24, 25; Fig. 124)
11. The sheet metal screws will be 12 inches apart along the outside crown of the sidelap. (20-25; Fig. 124)
12. The cleats should be spaced 12 inches apart. (20-32, 12; Fig. 126)
13. *a.* 49 cleats should be used. (20-32, 12; Fig. 126)
    b. The stretchout for the half with the pocket for the ridge cap should measure 10⅜ inches, and the stretchout for the half without the pocket should measure 9⅝ inches. (20-32; 2-13, 3, 6; Fig. 126)
    c. Because the double seamer will not make bends less than ¾ inch high. The conventional seamer and mallet are used to make a grooved (flat) seam from the standing seam along the ridge cap. (20-33, 19; Fig. 126)
14. A wire brush or emery cloth is needed to clean the surface to be soldered. (20-44; and Vol. 2)
15. Remove the self-tapping screws from the endlaps and sidelaps of sheet B, slip the sheet down the roof until it clears sheet E endlap, raise sheet D at the sidelap, and remove sheet B. To install a new sheet B, raise sheet D and insert sheet B to make a sidelap, raise sheet E and slide sheet B to make the endlap, and replace the self-tapping screws at all sidelaps and endlaps. (20-45, 25, 26; Fig. 124)

Section 21

1. The maximum bend that can be made is 90° if the pocket is formed on the bottom piece. A bend greater than 90° would not allow the metal to slip over the top flange of the roofing. (21-5; Fig. 127)
2. The wide gage double seamer is best suited because the seam is 1 inch high when completed. (21-5; 20-19; Fig. 127)
3. Gable flashing, eave flashing, and ridge flashing. (21-5, 6, 7; Fig. 127)
4. The stretchout is 6⅞ inches 1½ inches for the strip pocket, ⅝ inch for the roof thickness, 4 inches over the roof, and ¾ inch for the grooved seam). (21-6; Fig. 126)
5. Joints 1 and 3 will be straight on one end to fit into the expansion joint and will have the other end bent 180° to make a grooved seam. Joint 2, the center joint, will be bent 180° on both ends. (21-9, 10; Fig. 130)
6. Five expansion joints need to be fabricated. (21-17; Fig. 130)
7. The metal flashing should lap over piece A of the expansion joint 2¼ inches if a ¼-inch expansion allowance is made. (21-17, 4; Figs. 130, 132)

Section 22

1. The corner miters and the downspout drop outlet change the direction of the flow in the gutter. (22-3; Fig. 134)
2. The spike should be 8 inches long, and the ferrule should be 5 inches long. (22-8; Fig. 136)
3. The chalk line is used to mark the straight line (with a ¼-inch drop) for the hangers, which are installed before the straight section of gutter. (22-20, 21; Fig. 134)
4. The hanger braces in C, D, and E of figure 136 can be raised and lowered during the gutter installation because the brackets have several holes for height adjustment. (22-21, 9; Fig. 136)
5. Four hangers are required. (22-21; Fig. 134)
6. 29 inches. (22-22; Fig. 134)
7. Allow approximately $\frac{1}{16}$ for expansion. (22-23; 20-2; Fig. 134)
8. Because the back is 5 inches, the bottom is 3⅞ inches, the flange below the first ogee bend is ½ inch, each ogee bend is 2$\frac{3}{16}$ inches, the bead is ½ inch, and the hem is ¼ inch. When added together, these measurements make a total of 15 inches. (22-29; Fig. 139)
9. *a.* The stretchout for the 5-inch ogee gutter is 12 inches. (22-29; Fig. 139)
    b. Three 10-foot lengths of gutter can be made from a 3′ x 10′ sheet. (22-29; Fig. 139)
    c. The gutter would be formed in the same sequence as the 6-inch gutter. (22-31, 32; Fig. 140)
10. Your sketch should show that bends number 1, 2, 3, 6, 7, 8, and 9 are necessary. (22-31, 32; Figs. 135, 140)
11. Bends number 1, 2, 3, 7, and 9 should be made as shown in figure 141. Bend number

8 will be 60°, and bend number 6 will be 60°. (22-31, 32; Figs. 135, 141)

12. The flanges and tabs for the outside corner miter will be changed to piece 2. and the flanges and tabs for the inside corner miter will be changed to piece 3. (22-37; Fig 144)
13. Because the inside of the drop outlet is ½ inch from the wall. (22-41; Fig. 146)
14. The distance should be 3½ inches. (22-41; Fig. 146)
15. The miter angles will be 15° on each side of the center. (22-41; Fig. 146)

STOP— 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

53350 03 21

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course." "volume." and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Use a clean eraser for any answer sheet changes, keeping erasures to a minimum.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.

   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks.

   Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. The form number of this VRE (or CE) must match
   a. my course number.
   b. the number of the Shipping List.
   c. the form number on the answer sheet.
   d. my course volume number.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a
   a. pen with blue ink.
   b. pen with black ink.
   c. number 1 black lead pencil.
   d. ball point or liquid-lead pen.

3. If I tape, staple or multilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet,
   a. I will receive a new answer sheet.
   b. my answer sheet will be unscored or scored incorrectly.
   c. I will be required to retake the VRE (or CE).
   d. my answer sheet will be hand-graded.

CHAPTER 1

4. (301) What is the maximum number of 12-inch *flat* S-slips with 1⅛-inch pockets that can be made from a 12- x 14-inch piece of sheet metal?
   a. Two. c. Five.
   b. Four. d. Six.

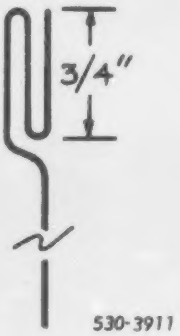
5. (300) How much allowance should be added to the stretchout for an offset lap seam in gage sheet metal that will be riveted with 2½-pound tinner's rivets?
   a. ¼ inch. c. ½ inch.
   b. ⅜ inch. d. ¾ inch.

6. (300) How much allowance should be made for the two sides of a 1-inch standing seam if 24-gage (0.025-inch) sheet metal is used?
   a. 4⅛ inches. c. 2.050 inches.
   b. 3 1/16 inches. d. 1.025 inches.

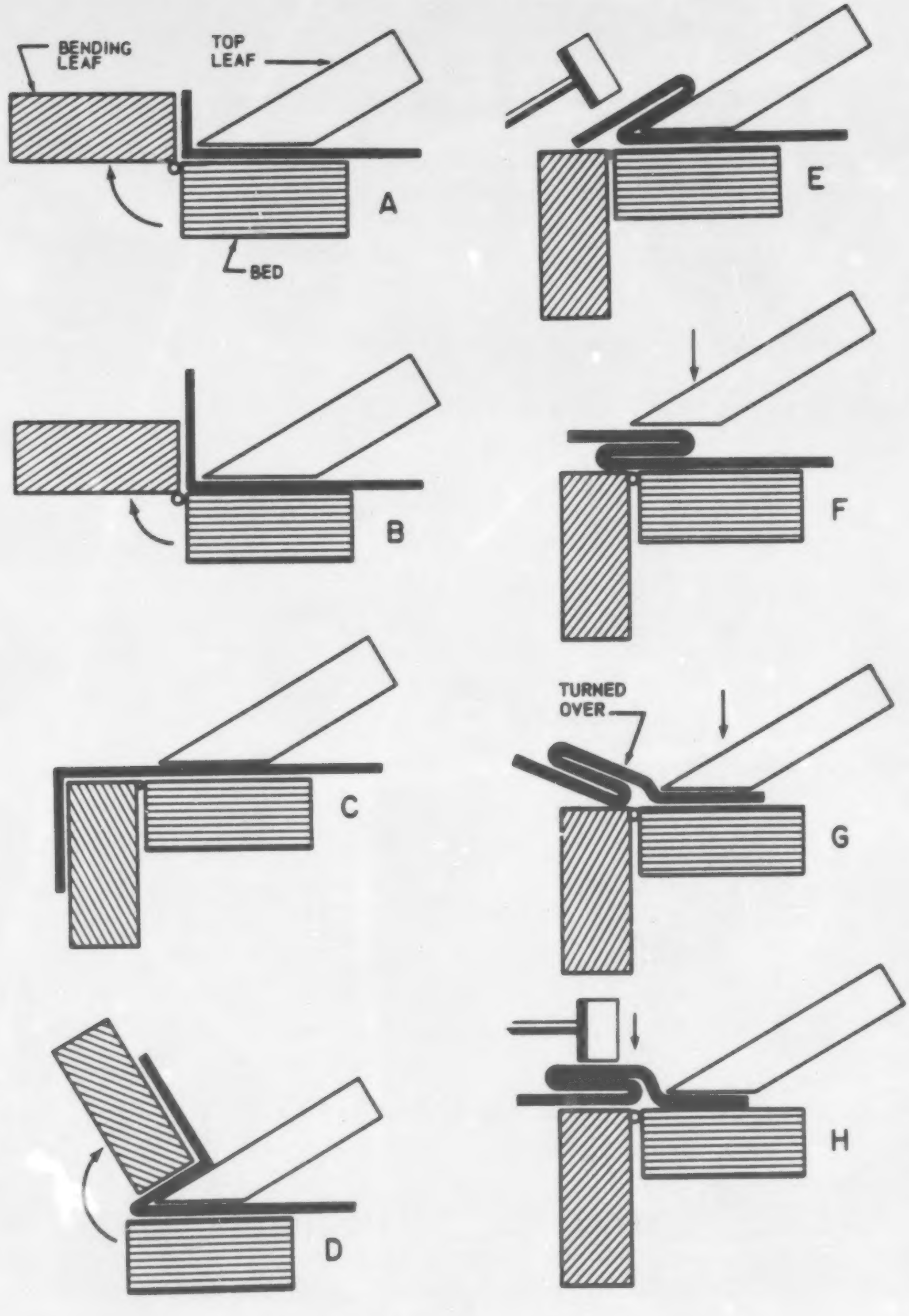
7. (300) You are to fabricate a joint of rectangular duct from 24-page sheet metal that is 12 inches high, 24 inches wide, and 36 inches long. If it is to have one riveted corner lap seam, what will be the width of the stretchout including seam allowance?
   a. 72¼ inches. c. 72¾ inches.
   b. 72½ inches. d. 73 inches.

8. (300) You are examining a Pittsburg lock seam that another airman has made on on the cornice brake. The seam measures and looks like the one shown in Volume Review Exercise Figure 1. What step shown in Volume Review Exercise Figure 2 did he perform *incorrectly?*
   a. Step C. c. Step G.
   b. Step D. d. Step H.

9. (301) In pattern A of figure 32 of the text, if the cross brakes are bent down instead of up, which of the *other* bends would require a change of bend direction?
   a. 25° bends.
   b. 90° bends.
   c. 180° bends.
   d. All of the above.



Volume Review Exercise Figure 1.


BENDING LEAF
TOP LEAF
BED
A
B
C
D
E
F
TURNED OVER
G
H

Volume Review Exercise Figure 2.

10. (300) How much seam allowance should be made on 24-gage (0.025-inch) sheet metal if a grooved seam is to be made with the Pittsburg lock forming machine which makes a ½-inch grooved seam?

a. 1⅛ inches.
b. $1\frac{3}{16}$ inches.
c. 1⅝ inches.
d. $1\frac{11}{16}$ inches.

11. (301) A takeoff fitting, such as illustrated in figure 29 of the text, has been fabricated and is being assembled. The throat piece is a perfect fit. What was done incorrectly if the heel piece does not fit because it is ½ inch too short?

a. Pattern B was made incorrectly.
b. Tapped connection was formed too short.
c. The allowance for the radius was not allowed.
d. Not enough allowance was made for the tapped connection.

12. (300) What is the formula for determining the seam allowance for a bottom double seam in light gage sheet metal? Let the letter W represent width of the seam and T represent thickness of the metal.

a. 2W + 2T.
b. 2W + 3T.
c. 3W + 5T.
d. 3W + 2T.

13. (301) What mistake was made if the bottom pattern in figure 31 of the text is too short in length to fit the side piece?

a. The length of the sides wasn't correctly figured for the slant length.
b. The bottom piece should have been cut the same length as the top pattern.
c. The 1-inch straight bend was made at too great an angle.
d. Allowance for the Pittsburg lock seam was made only on one side.

14. (301) Which type of joint connection should you select to provide maximum strength to duct joints that are 10 inches high, 28 inches wide, and 36 inches long?

a. Flat S-slip.
b. Drive slip.
c. Standing S-slip.
d. Reinforced standing S-slip.

15. (300) How far will the tabs be cut if a dovetail seam is being made at the 30° mitered end of a cylinder?

a. ¼ inch.
b. ½ inch.
c. ¾ inch.
d. 1 inch.

16. (301) What mistake was made in the fabrication of a standing S-slip, such as shown in figure 23 of the text, if one of the pockets measures only 1 inch and all the other dimensions are correct?

a. Not enough material was allowed for the undersized pocket.
b. Allowance was not made for the standing edge.
c. The material slipped in the cornice brake.
d. The third bend was made incorrectly.

17. (300) What is the length of a stretchout, including seam allowance, for an 8-inch by 12-inch duct made of 24-gage sheet metal that will be joined with a corner double seam?

a. 40¼ inches.
b. $40\frac{9}{16}$ inches.
c. $40\frac{13}{16}$ inches.
d. 40⅞ inches.

18. (300) What is the likely mistake in the fabrication of a standing seam (such as step A in fig. 13 of the text) that is to be formed into a grooved seam if the sides of the channel are ¼ inch too long on one side and ¼ inch too short on the other?

a. The brake line was not marked in the proper place.
b. Not enough seam allowance was made.
c. Too much seam allowance was made on on the long side.
d. The brake line on the long side of the channel piece was bent first.

19. (301) A 5-foot joint of 14- x 30-inch duct is to be fabricated with Pittsburg seams at each corner joined with standing S-slip and drive slip connectors at each end, and strengthened with cross braking and 1-inch standing seams across the top and bottom sides. What will be the total length of metal needed for the top side of the joint?

a. The center-to-center distance.
b. The center-to-center distance plus the standing seam allowance.
c. The center-to-center distance plus the standing seam allowance plus the S-and-drive slip allowance plus the Pittsburg seam allowance.
d. The center-to-center distance plus the standing seam allowance plus the S-and-drive slip allowance.

20. (301) What is the maximum number of 1⅛-inch drive slips 12 inches long that can be made from a 12- x 20-inch piece of sheet metal?

a. Five. c. Nine.
b. Eight. d. Seventeen.

21. (301) What gage of galvanized iron is best suited to obtain maximum strength in a duct 48 inches wide that will have standing S-slips on 35-inch centers?

a. 22-gage. c. 26-gage.
b. 24-gage. d. 20-gage.

22. (301) What will be the total length (including allowances) of a pattern for a duct joint that will be 28 inches long if it has 1⅛-inch S-slip and drive slip connectors at each end?

a. 28½ inches. c. 29⅛ inches.
b. 29 inches. d. 30 inches.

23. (300) What is the formula for determining the allowance for a grooved seam in light gage sheet metal? Let the letter W represent width of the seam and T represent thickness of the metal.

a. 3W + 3T. c. 2W + 2T.
b. 3W + 5T. d. 2W + 3T.

CHAPTER 2

24. (304) What size hole would you make in the ceiling if the diffuser frame in view B of figure 48 of the text is for a 6-inch outlet?

a. The diameter of the flange on the diffuser frame.
b. The diameter of the diffuser frame.
c. The diameter of the diffuser gasket.
d. The diameter of the duct outlet.

25. (303) How many turn vanes should be used in an elbow in a rectangular duct that is 14½ inches wide and 10 inches high (deep)?

a. Five. c. Ten.
b. Six. d. Twelve.

26. (303) What is the probable cause if the top blade of the louver damper in figure 45 of the text is sticking and prevents the damper from completely closing?

a. The damper blade is not installed in the center of the duct.
b. The blade is striking the bolthead.
c. Broken linkage.
d. Sagging duct.

27. (302) How can airflow be increased through a heating coil in a diverging-converging section of a duct?

a. Increasing the diverging angle.
b. Installing splitters in the diverging section.
c. Increasing the size of the heating coil.
d. Shortening the length of the diverging section.

28. (304) If you want to allow ⅛-inch clearance on each side of the air return grille in room 7 shown in foldout 1, what size hole should you have the carpenter cut for the blade frame?

a. 12 x 6 inches.
b. 12⅛ x 6⅛ inches.
c. 12¼ x 6¼ inches.
d. 12½ x 6½ inches.

29. (304) What installation mistake was made if a multiple blade register, such as shown in figure 49 of the text, is not plumb?

a. The duct is not square on one side.
b. The ¾-inch flange on the duct is too small.
c. One side of the register face frame is not square.
d. The register wasn't held straight when used as a template.

30. (303) How many splitters should be installed inside an elbow that is 6¾ inches wide, has an 11½-inch throat radius, and connects two rectangular duct sections?

a. None. c. Two.
b. One. d. Three.

31. (303) A duct system has been installed and there is *no* airflow through a branch line which has a butterfly damper with the control quadrant handle in the full OPEN position. What is the best procedure to restore the butterfly damper to correct operation?

a. The rivets holding the control quadrant should be removed, the quadrant rotated 90°, then the quadrant riveted in the new position.

b. The control handle should be removed, turned 90°, replaced on the square shaft, then moved to the OPEN position.
c. The S-and-drive slips should be removed from both ends of the duct joint and the damper blade removed, turned 90°, then replaced in the new position.
d. The handle should be moved to the SHUT position, and a note painted on the duct "OPEN IS SHUT and SHUT IS OPEN."

CHAPTER 3

32. (308) What are the dimensions (including allowances) of a piece of sheet metal that will make joint 14 of trunk line C in figure 60 of the text?

a. 4'9" x 41¼".
b. 4'9" x 40".
c. 4'8" x 20¼".
d. 4'8" x 20".

33. (311) What is the distance from the ceiling to the centerline of the 16" x 10" to 14" x 8" transition in trunk line B of foldout 1?

a. 20 inches.
b. 24 inches.
c. 25 inches.
d. 28 inches.

34. (305) How many types of joint connections are used in the supply and return air duct systems illustrated in foldout 1?

a. Two.
b. Three.
c. Four.
d. Five.

35. (311) How many hangers are needed for trunk line C in figure 60 of the text if the hangers are installed on 48-inch (approximate) centers?

a. Nine.
b. Ten.
c. Eighteen.
d. Twenty.

36. (305) How many breakdowns would trunk line C of foldout 1 have if the duct should be changed to end where the last transition joins the 14" x 8" duct section?

a. Two.
b. Three.
c. Five.
d. Seven.

37. (306) What size piece of sheet metal is needed to make joint 14 of trunk line C in figure 60 of the text?

a. 41¼" x 57".
b. 40" x 56".
c. 36" x 41¼".
d. 35" x 40".

38. (305) The center of the diffuser outlet in room 3 of foldout 1 is located 7'6" from the trunk line. How long will the 8-inch straight section in the latrine need to be if the 8-inch diffuser is to be in the line with the one in room 3?

a. 6'2".
b. 6'4".
c. 7'6".
d. 7'8".

39. (308) The turn vane pattern in figure 69 of the text has instructions to make the ¾-inch slits 1 inch apart. However, since the 1-inch spacing is an approximate figure, what should the spacing be in this example to make the slits equal distances apart (to the nearest 1/16 inch)?

a. 15/16 inch.
b. 1 inch.
c. 1 1/16 inch.
d. 1¼ inch.

40. (310) A hand folder, such as shown in figure 71 of the text, is a desirable tool when forming the patterns of

a. rectangular joints.
b. round duct joints.
c. plenum covers.
d. elbows.

41. (311) If 1-inch foil-backed insulation 48 inches wide is used to wrap the branch line in the hallway of figure 57 of the text, how many pieces (some cut to widths less than 48 inches) are needed?

a. One.
b. Two.
c. Three.
d. Four.

42. (306) In trunk line C (fig. 60 of the text), how much material will be required to make the standing S-slips and drive slips for joints 9 through 15? (These are similar to those shown on sheet 7 of figure 59 of the text.)

a. 36" x 51¼".
b. 36" x 63¼".
c. 36" x 75¼".
d. 36" x 79".

43. (310) Step B of figure 74 of the text is the inside view of the pattern. Which of the following should be bent up along the bend lines?

a. ¼-inch Pittsburg flange.
b. Drive slip connection.
c. S-slip connection.
d. Double seam.

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44. (307) Which of the following ducts can be wrapped with a single piece of foil-backed glass fiber insulation 48 inches wide without trimming the width of the material? (The seam allowance is 6 inches.)

a. 6″ round duct.
b. 8″ round duct.
c. 7″ x 14″ rectangular duct.
d. 12″ x 14″ rectangular duct.

45. (308) The pattern for the cover for joint 6 of trunk line A is similar to figure 66 of the text. What will be the dimensions (including allowances) of the pattern of the cover for joint 6?

a. 14″ x 10″.
b. 26″ x 16″.
c. 28″ x 18″.
d. 28″ x 28″.

46. (306) How much material will be required to make the pattern (including allowances) for the drop joint in the latrine of foldout 1?

a. 8″ x 25⅛″.
b. 9½″ x 26⅛″.
c. 11″ x 18⅞″.
d. 12½″ x 19⅞″.

47. (308) What are the dimensions (including allowances) of a piece of sheet metal that will make the 6-inch joint that connects the room 10 branch line to trunk line C in figure 60 of the text?

a. 19⅛″ x 6″.
b. 19⅞″ x 6½″.
c. 25⅛″ x 7″.
d. 25⅞″ x 7½″.

48. (312) Which one of the following items of cutting equipment is best suited to cut patterns B and C which are shown in figure 78 of the text?

a. Squaring shears.
b. Throatless shears.
c. Utility shears.
d. Portable unishears.

49. (311) What size hole should be cut for installation of the return air grille in the door of room 7 as shown in foldout 1?

a. 12″ x 6″.
b. $12\frac{1}{16}$″ x $6\frac{1}{16}$″.
c. 12⅛″ x 6⅛″.
d. 12¼″ x 6¼″.

50. (306) How much material will be required to make the pattern for the 25½-inch joint in the latrine branch line of trunk line C (fig. 60 of the text)?

a. 19⅞″ x 25⅛″.
b. 25⅛″ x 25½″.
c. 26⅛″ x 27″.
d. 26⅛″ x 36″.

51. (308) When developing a pattern for the gores of an 8-inch elbow, what will be the length of the working line?

a. 18⅞ inches.
b. 25⅛ inches.
c. 25⅞ inches.
d. 26⅛ inches.

52. (312) When joints 14 and 15 (shown in fig. 77 of the text) are removed and the drive slips are removed from each end of joint 12, what will interfere with the removal of joint 12?

a. S-slip allowances.
b. Hangers.
c. Pittsburg lock seams.
d. Turned edges of the drive slip allowances.

53. (312) If the patterns for joint 12 in figure 78 of the text are cut from sheets of metal 4 feet wide, how much material will be needed? (This includes having a minimum of leftover pieces.)

a. One sheet 4′ x 10′.
b. One sheet 4′ x 10′ and one piece 4′ x 6′2″.
c. Two sheets 4′ x 8′ and one piece 4′ x 6′3″.
d. Three sheets 4′ x 8′.

54. (311) How long will a 1-inch strip of 16-gage sheet metal need to be to make a single hanger (such as shown in fig. 76 of the text) for an 8-inch round duct whose centerline is 36 inches from the supporting rafters? (The hanger will lap 4 inches on the rafter.)

a. 41 inches.
b. 59⅞ inches.
c. 62⅛ inches.
d. 105⅛ inches.

55. (309) Which of the following joints (shown in fig. 60 of the text) have patterns that do *not* require notching or slitting?

a. Joint 3.
b. Joint 13.
c. The elbow in the latrine branch line.

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d. The 34½-inch joint in the latrine branch line.

56. (312) When forming pattern A of figure 78 of the text, which of the following items of bending and forming equipment is *not* needed?

a. Mallet.
b. Cornice brake.
c. Burring machine.
d. Slip roll machine.

57. (310) When forming the following items, which one *cannot* be made quicker if a Pittsburg lock forming machine is used?

a. Plenum top.
b. Elbow.
c. Round duct joint.
d. Flexible connection.

58. (312) Joint 12 shown in figure 77 of the text is a tight fit, and for installation it is decided to cut off the ½-inch S-slip allowances between joints 11 and 12 and between joints 12 and 13. How many new heavy-duty S-slips with 2-inch pockets are needed to install joint 12?

a. Two.
b. Four.
c. Six.
d. Eight.

59. (305) What gage of galvanized sheet iron or what gage of aluminum should be used to fabricate the plenum chamber of the duct system shown in foldout 1?

a. 22-gage galvanized or 20-gage aluminum.
b. 22-gage galvanized or 22-gage aluminum.
c. 24-gage galvanized or 22-gage aluminum.
d. 26-gage galvanized or 24-gage aluminum.

60. (310) How many 90° bends are required for the patterns of rectangular joints such as shown in figure 63 of the text?

a. Three.
b. Four.
c. Five.
d. Six.

61. (311) What is probably wrong with the installation of a diffuser, such as shown in figure 48 of the text, if it is ⅛ inch from the ceiling on one side?

a. The ceiling is ⅛ inch high on one side.
b. The ceiling is ⅛ inch low on one side.
c. The duct is ⅛ inch short on one side.
d. The damper ring is ⅛ inch low on one side.

62. (305) What type of lock seam should be selected for the corners of rectangular ducts, such as the trunk lines in foldout 1, if each joint is to be made from two pieces of sheet metal?

a. Pittsburg lock seam.
b. Corner lap seam.
c. Standing seam.
d. Grooved seam.

CHAPTER 4

63. (314) The collar of a stack assembly, such as shown in figure 85 of the text, is "rusted out." What parts of the assembly probably need replacement?

a. The stack, vent cap, and flashing.
b. The roof jack, stack, and vent cap.
c. The collar, roof jack, and stack.
d. The collar, stack, and vent cap.

64. (314) Refer to view A of figure 89 of the text. If the distance from A to C in the plan view is 7/16 inch, what should the cutout (arc) measurement be (to the nearest 1/16 inch and less seam allowances)?

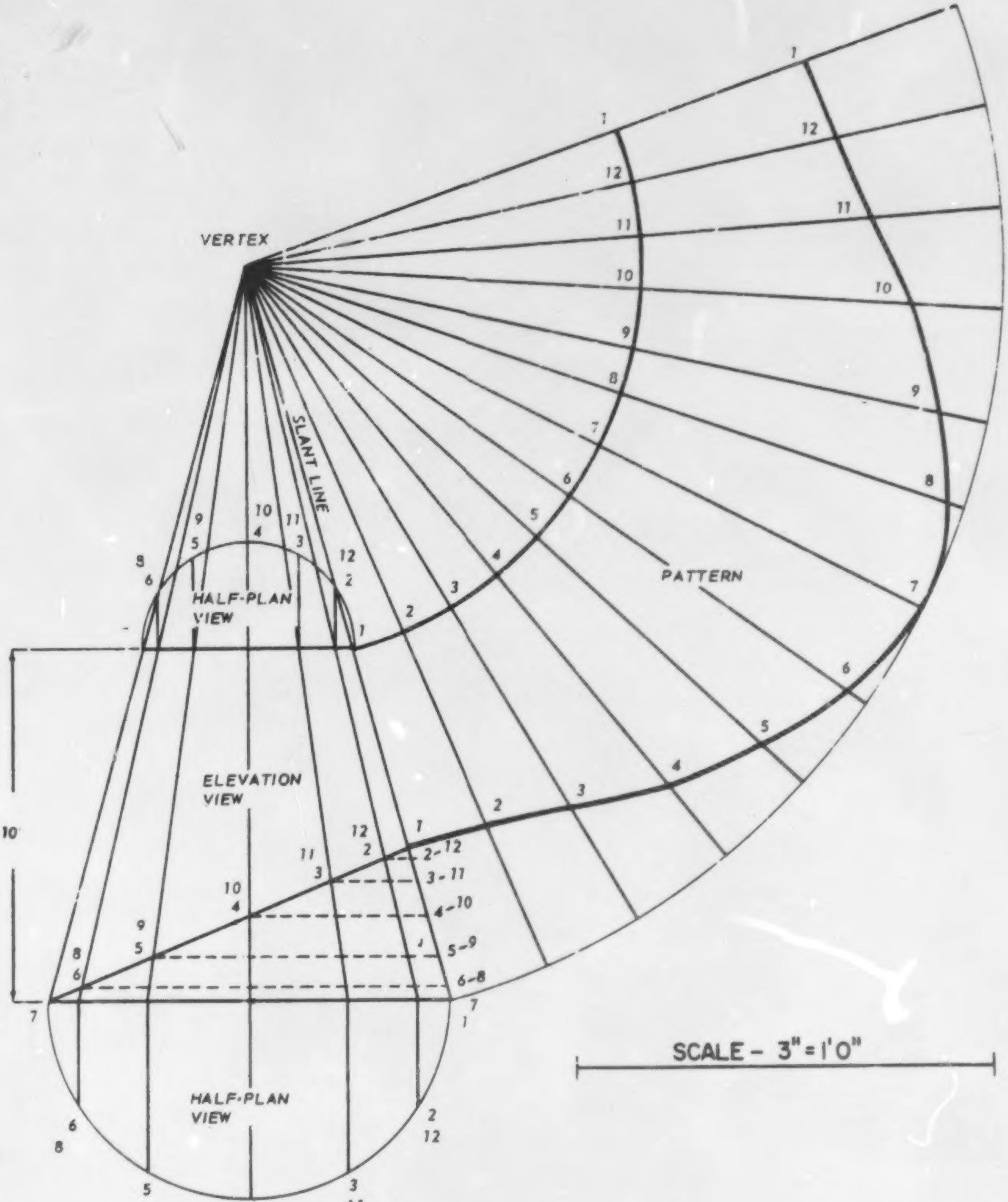
a. 2½ inches.
b. 2⅝ inches.
c. 2¾ inches.
d. 3 inches.

65. (314) What is the radius of a stack brace assembly, such as shown in figure 91 of the text, if the inside diameter of a double-wall stack is 3 inches?

a. 3 inches.
b. 2½ inches.
c. 2 inches.
d. 1½ inches.

66. (313) Which joint in figure 81 of the text is best suited to correct for a 1-inch error in the vertical centerline of a heater stack?

a. Round tee joint.
b. Adjustable "L" offset.
c. 45° adjustable elbow.
d. 90° adjustable elbow.


VERTEX
SLANT LINE
HALF-PLAN VIEW
ELEVATION VIEW
PATTERN
HALF-PLAN VIEW
10"
SCALE - 3" = 1'0"
1
12
11
10
9
8
7
6
5
4
3
2
1
2-12
3-11
4-10
5-9
6-8
7
1

Volume Review Exercise Figure 462

67. (314) What is the probable error if the heating unit collar (shown in fig. 80 of the text) and the cutout for the ceiling thimble are in alignment but the outlet for the roof jack is off center?

    a. The plumb bob was not held in the center of the ceiling cutout.
    b. The roof jack outlet was laid out for a 3 to 12 pitch.
    c. The allowance for the roof pitch was not made.
    d. The heating unit collar is not properly aligned.

68. (315) When is the V-groove formed around the top of the transition that is shown in figure 94 of the text?

    a. Between the steps for forming the grooved seams and the steps for forming the 22½° element lines.
    b. After the grooved seams are molded on the Pittsburg lock forming machine.
    c. Before the element lines are bent.
    d. When the collar is formed.

69. (315) When installing a draft ventilator, such as shown in view B of figure 92 of the text, where is the roofing felt located?

    a. Between the flashing and the roof deck.
    b. On top of the transition base.
    c. Under the roof deck.
    d. Between the flashing and the roofing tar (asphalt).

70. (314) Each element line shown on the pattern in Volume Review Exercise Figure 3 is the same length as one other element line—except for one. Which element line does *not* have the same length as any other?

    a. 3.
    b. 5.
    c. 7.
    d. 9.

CHAPTER 5

71. (317) Which of the following series of grinding wheel grits should be used with the portable grinder when preparing a stainless steel weld for buffing?

    a. 24 to 60 to 40.
    b. 24 to 60 to 80.
    c. 160 to 80 to 24.
    d. 160 to 80 to 120.

72. (318) You are replacing the bottom of the shower stall shown in figures 105 and 106 of the text. What will be the dimensions of the sheet metal when the pattern is cut with the squaring shears (before notching)?

    a. 30″ x 32″.
    b. 31½″ x 33½″.
    c. 32″ x 32″.
    d. 34″ x 34″.

73. (316) How much stainless steel is needed to make the pattern, including seam allowances and additions, for the left side of the hood shown in figure 98 of the text?

    a. 30″ x 55$\frac{7}{16}$″.
    b. 34⅛″ x 44½″.
    c. 34⅛″ x 55$\frac{7}{16}$″.
    d. 36$\frac{7}{16}$″ x 96″.

74. (317) How much allowance is made for the butt joints between the stainless steel front panels of the serving line counter shown in figure 101 of the text, if the joints are covered with cap strips?

    a. None.
    b. ½ inch.
    c. 1½ inches.
    d. 2 inches.

75. (316) What part of the side pattern shown in figure 98 of the text is protected from unnecessary bending if the box and pan brake is used instead of the cornice brake?

    a. Hem addition.
    b. Skirt addition.
    c. Collar addition.
    d. Standing seams.

76. (318) What tool or piece of equipment will be the best choice to make *all* of the rivet holes needed to assemble the shower stall shown in figure 105 of the text?

    a. Rotary punch.
    b. Whitney hand punch.
    c. Hand drill and twist drills.
    d. ¼-inch electric drill and twist drills.

77. (318) What kind of seams are used to join the metal pieces on the door which is shown in figure 107 of the text?

    a. Standing and grooved seams.
    b. Pittsburg lock seams.
    c. Corner lap seams.
    d. Offset lap seams.

78. (316) In figure 96 of the text, what is the length of each standing seam?

a. 44¾ inches. c. 47¼ inches.
b. 45½ inches. d. 54 inches.

79. (319) A replacement is to be made for the 10th panel on the top of the canopy (as shown in fig. 112 of the text). What will be the dimensions of the metal when cut with the squaring shears?

a. 4′ x 8½″. c. 5′ x 6½″.
b. 4′ x 9⅞″. d. 5′ x 9⅞″.

80. (318) When the shower stall back piece shown in figure 106 of the text is run through the Pittsburg lock forming machine, the pockets should be

a. on one side only.
b. on the outside.
c. on the inside.
d. facing different directions.

81. (319) What type of fasteners are used to to attach the back trim piece to the aluminum angle piece of the canopy shown in figure 112 of the text?

a. Machine screws.
b. Sheet metal screws.
c. Lag screws.
d. Wood screws.

82. (319) If ¼-inch aluminum rivets are used to fasten the corner brackets to the corners of the canopy shown in figure 112 of the text, what size twist drill should be used to make the rivet holes?

a. 15/64 inch. c. 17/64 inch.
b. ¼ inch. d. 9/32 inch.

83. (319) You have made a new brace for the awning shown in figure 110 of the text. A ¼-inch lag screw is to be used to make a tight fit in the old hole of the wooden window frame. What size hole should be drilled in the metal brace?

a. 3/16 inch. c. ⅜ inch.
b. 5/16 inch. d. 7/16 inch.

84. (318) You are replacing the bottom front piece of the shower stall shown in figure 105 of the text. To remove the rivets, you have a ¼-inch electric drill, a twist drill that is the same size as the shank of the rivets, a file, a drift punch, and a hammer. One tool is missing; what is it?

a. Cleco. c. Hacksaw.
b. Grinder. d. Center punch.

85. (318) If the bottom piece of the door shown in figure 107 of the text is to be replaced, how many grooved seams will need to be opened so that the piece can be removed from the bottom of the door?

a. Three. c. Eight.
b. Six. d. Twelve.

86. (317) You are making a replacement bracket, such as that shown in figure 103 of the text, for 14-gage (0.064-inch-thick) 1-inch diameter tray slide rails. What size holes should you punch in the bracket pattern?

a. 2 inches. c. ½ inch.
b. 1 inch. d. 0.064 inch.

87. (318) The 3½-inch drain hole in the bottom piece of the shower stall shown in figure 106 of the text can be cut with any of the following *except*

a. a hole saw.
b. aviation snips.
c. a circle (fly) cutter.
d. circle shears.

88. (316) When installing a hood with the hanger part shown in figure 99 of the text, what will be the easiest piece to remake if one of the hangers is 2 inches too short?

a. The short ⅜-inch rod.
b. The long ⅜-inch rod.
c. The corner connector.
d. The flat bar.

89. (319) If the awning shown in figure 110 of the text is to be installed in a concrete (cinder) block building, what is used to hold the screws in the holes of the wall?

a. Clips.
b. Cement.
c. Expandable sleeves.
d. Nothing, if the holes are the correct size.

90. (316) The patterns shown in figure 98 of of the text are cut and assembled, and the hood is suspended on the hangers. What

will you see at each corner of the grease trap when standing under the hood?

a. 90° butt joints.
b. Standing seams.
c. 45° miter lap seams.
d. Soldered drain outlet.

CHAPTER 6

91. (321) How many bends are required if the fascia flashing shown in figure 131 of the text is being formed with two V-stiffeners?

a. Five. c. Nine.
b. Seven. d. Ten.

92. (321) What are the bending instructions for the 8-foot center joint of the 24-foot section of copper fascia shown in figure 130 of the text?

a. Bend one end down 180° and leave the other end straight.
b. Bend both ends down 180°.
c. Bend both ends up 180°.
d. Bend one end down 180° and one end up 180°.

93. (322) In figure 134 of the text, the lengths of the gutter sections are shown. If the corner miters are 6 inches long on each side of the turn, how much straight gutter will be needed for the installation?

a. 6 feet. c. 10 feet.
b. 8 feet. d. 12 feet.

94. (321) How much of the flashing will lap under piece B of the expansion joint shown in figure 132 of the text if copper fascia and gravel flashing is being installed to allow for ¼ inch of expansion?

a. 1 inch. c. 2 inches.
b. 1¼ inches. d. 2¼ inches.

95. (320) Which of the following number of sidelaps are possible when joining two sheets of 5 V-crimp metal roofing, such as shown in figure 114 of the text?

a. One and one-half.
b. Two.
c. Three.
d. Four.

96. (320) If you are installing sheets of 5 V-crimp metal on the roof shown in figure 124 of the text, where would the sheet metal screws be installed for a double sidelap?

a. Twelve inches apart in the valley of the sidelap.
b. On the second crown of the sidelap at each purlin.
c. Twelve inches apart on the first crown of the sidelap.
d. Twelve inches apart on the outside crown of the sidelap.

97. (322) What is the stretchout for the 4-inch gutter shown in figure 139 of the text?

a. 8 inches. c. 12 inches.
b. 10 inches. d. 15 inches.

98. (320) Which of the following is correct if the roof in figure 124 of the text is made of galvanized iron and sheet B is being replaced?

a. Sheet B should lap under sheets D and E.
b. Sheet B should lap over sheets D and E.
c. Sheet B should lap under sheet E and over sheet D.
d. Sheet B should lap under sheet D and over sheet E.

99. (320) If the roof deck shown in figure 126 of the text is ⅝ inch thick, how much metal is needed to lap over the gable edge and form the pocket shown in view D?

a. 2 inches. c. 2 3/16 inches.
b. 2⅛ inches. d. 2⅝ inches.

100. (322) How many 22½° miter lines were required to make the 45° notches (before assembly) for the shoe shown in figure 146 of the text?

a. Two. c. Four.
b. Three. d. Six.

101. (320) Which of the following listed roofing tools should be used to form 1-inch double standing seams on a metal roof?

a. Wide gage double seamer and clamping tongs.
b. Common gage double seamer and squeezing tongs.
c. Common gage seamer and adjustable folder.
d. Hand seamer and ¾-inch conventional seamer.

102. (322) What is the minimum number of hangers that should be installed on the front of the building shown in figure 134 of the text if the distance between the end cap and the outside corner miter is 8 feet instead of 6 feet?

a. Six.
b. Five.
c. Four.
d. Three.

103. (322) How many 90° bends are required if you are to form a gutter with straight sides like the one shown in figure 135 of the text?

a. Three.
b. One.
c. Two.
d. Four.

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CDC 53350

SHEET METAL SPECIALIST

(AFSC 53350)

Volume 4

Supervision and Management

13-1

Extension Course Institute

Air University

467

DEPARTMENT OF THE AIR FORCE
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UNITED STATES OF AMERICA

PREPARED BY
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THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

SUPERVISION AND management are generally thought of as the responsibilities of sheet metal supervisors and metalworking superintendents; however, if you examine the specialty description for sheet metal specialist, you will find that 5-level sheet metal specialists also have supervisory responsibilities. Therefore, this volume has been prepared to meet the specialty training standard (formerly job training standard) requirements for supervision and management.

From this volume, you can obtain a basic understanding of the principles and procedures of supervision and management. The volume deals with supervisory responsibilities; supervision of sheet metal fabrication and repair; and how to determine job requirements, inspect and evaluate sheet metal shops, plan and schedule work activities, manage personnel, and conduct on-the-job training.

Since this volume is primarily for airmen in training for AFSC 53350, you should study all of the text, answer all of the Chapter Review Exercises, and answer all of the Volume Review Exercises. Upon satisfactory completion of this volume, the Course Examination, and your proficiency training (OJT), you should be ready for the course examination (CE).

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC) Chanute AFB, ILL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of October 1971.

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CHAPTER 1

Supervisory Responsibilities and Personnel Management

THIS CHAPTER deals with the supervisory duties and responsibilities of metalworking superintendents, sheet metal supervisors, and 5-level sheet metal specialists. An introduction to personnel management will also be covered in this chapter. At present you are primarily interested in the 5-level responsibilities; however, it is also necessary for you to be familiar with the 7- and 9-level responsibilities; however, it is also necessary for you to be familiar with the 7- and 9-level responsibilities so that you will know the extent of your duties and responsibilities and what to expect from your superiors. You will find that a thorough understanding of each level of supervision will help to promote harmony in the shop and will increase production. The success you have in performing 5-level supervisory duties will be a good indication of how well you may later perform at the 7 level. Your knowledge of supervisory responsibilities will be used and applied every day, because you will be supervising people who have less experience than you and coordinating with supervisors above you.

2. As a supervisor, you have a responsibility to your supervisor, to yourself, and to the people you are supervising. This doesn't mean that you have all of the weight on your shoulders, because together all of you make a team. If all know how to do their share and carry their share of the load, the jobs for each will be easier and will be better done.

3. Let's briefly think about some of the situations that can develop if you do not have adequate supervisory preparation. From the first day on as a supervisor, you will be confronted with many problems and situations requiring immediate action. These troubles multiply at an alarming rate, and you may begin to wish that you were back at the old job where life was pretty simple after all. Right from the start, a wrong decision, a careless remark, or a violation of a human relations principle may take months to straighten out. You suddenly become aware of the fact that you are up against more than you bargained for! This job of supervision is not as easy as it looked!

4. Some people cannot take this new responsibility. They find it too bewildering, too demanding, too uncomfortable. These people often request to be returned to their old jobs where they were responsible only for their own output, where someone else told them exactly what to do. Others go into a new job like a "bull in a china shop," making one mistake after another, until management is forced to remove them from the new position. Still others are too weak, too timid, too unintelligent, too immature, or too lacking in other factors of leadership required in supervisory positions. Generally they, too, fall by the wayside. But most of us somehow survive the shock, and eventually we learn to like the new work. Being a supervisor in a vital military establishment like the Air Force is a grave responsibility, but the rewards are great for those who can make the grade.

5. A worker may be an expert craftsman, but it does not follow that he would also be a good supervisor. Occasionally a person who is a very poor or a very lazy employee in lower positions turns out to be a very good supervisor or administrator. This is because he has learned the knack of getting work out of others and of getting along well with people. Now certainly management is much more than winning friends and influencing people, but the knack of getting others to work for you willingly is so important that a great deal of time in any supervisor training course is devoted to the subject of "Human Relations," the art of getting along with people. As a supervisor, you will be responsible for the output of others. You will seldom perform the actual production work yourself. You must be able to devise ways to get a good day's work out of those who work under you.

6. After you become a "53350" (and even as you are training toward this 5-level AFSC), you will begin assuming supervisory duties. Although you don't have the title of "assistant supervisor," you will discover that such a title is appropriate.

The first section of this chapter discusses the supervisory responsibilities that are expected of 5-level sheet metalworkers. Sections 2 and 3 discuss some of the responsibilities related to personnel management, such as personality traits of a leader, promoting harmonious relationships, resolving personnel problems, and using performance requirements. The principles and procedures discussed in this chapter can be applied to various personnel management situations that you will encounter in the sheet metal shop and in other Air Force activities.

1. Duties and Responsibilities

1-1. According to the Air Force Glossary of Standardized Terms and Definitions, supervision is the control exercised by a principal over his subordinates through direction, guidance, resources, and policy with respect to delegation of responsibility. Supervision includes power to remove or discipline the subordinates and to require reports to obtain information and evaluate performance.

1-2. A supervisor is someone who directs the efforts of other people. In civil engineering activities, he may be a civilian or military superintendent, foreman, working leader, sheet metal supervisor, or 5-level sheet metal specialist. Regardless of the title, a supervisor is a leader, manager, timekeeper, scheduler, evaluator, inspector, and counselor.

1-3. The duties and responsibilities of civilian supervisors are contained in the position description for the particular job. The duties and responsibilities of military supervisors are contained in the specialty descriptions of Air Force Manual 39–1, *Airman Classification Manual.* The Job Training Standard (JTS 53330/50/70) further describes each specialty in terms of general tasks, items of knowledge, and proficiency level accomplishments. The title "Job Training Standard (JTS)" has been changed to "Specialty Training Standard (STS)." Since you are in training for AFSC 53350, we will first discuss the 5-level supervisory duties and responsibilities, next the 7-level, and then the 9-level.

1-4. **Sheet Metal Specialist, AFSC 53350.** During your training period and later when you become a 5-level sheet metal specialist, your supervisory duties will be to assist the shop supervisor (foreman) in his duties. These duties, as listed in your specialty description, include the following items. Observe work performance to insure adherence to prescribed procedures. Improve work methods to obtain more efficient operation. Verify use of proper tools and equipment. Accomplish on-the-job training. Assign specific tasks to individual workers and inspect completed work for conformance with established standards. As the supervisor's assistant, you will need to have a basic understanding of the principles and procedures of supervision; and you will need guidance when performing involved or complicated supervisory operations.

1-5. Checking the performance of other workmen (trainees) requires you to be a proficient sheet metalworker, because you must make sure that each trainee selects the proper tools and equipment for the job, that he does the job correctly, and that he uses the tools and equipment safely. Sometimes you may be a crew leader who assigns tasks to the members of your crew. In this role, you not only assign the tasks but you also supervise the performance and inspect the completed work. When assigning tasks, make sure that your directions are simple, understandable, and specific. You should explain to the trainee how each task fits into the overall picture of the job. This shows the trainee the importance of completing the task correctly; and as he performs the task, you should check to see that any production problems are handled immediately.

1-6. Here is an example of a supervisory situation which might happen to you. Suppose the shop supervisor receives an AF Form 327 (Base Civil Engineer Work Order) and assigns you as the crew leader for the job. You will have to make work assignments to the men in your crew; and during the fabrication or installation, you should make sure the job is performed to the specifications required by the work order, drawing, or directives. As the crew leader, you must make sure that the workmen use correct tools and equipment and that they are doing the task in accordance with safety regulations and operating procedures. Upon completion of the job, you inspect for completeness, specifications, and workmanship. Any deficiencies should be reworked before turning the work order in to the shop supervisor. After the shop supervisor signs the work order off as completed, he turns it in to the superintendent.

1-7. Improving work methods is another responsibility of yours. The fact that you are an apprentice does not mean that your ideas are worthless. Discuss any constructive ideas that you may have with your supervisor, because improvement of work methods is also one of his duties. Suppose you are in a shop where there is only one scrap metal box; and scraps of aluminum, stainless steel, copper, and galvanized iron are mixed together. When the metal is taken to the marketing and redistribution section, it has to be separated. You feel that this is a problem and is causing wasted man-hours. A solution to the problem could be to have a storage box made for each type of metal so that each type can be collected separately. Some ideas you have for improving work methods may be good enough to justify submission on a suggestion form, with the possibility of receiving a cash award.

1-8. Conducting on-the-job training is often assigned to 5-level sheet metal specialist. This doesn't mean responsibility for the whole training program but responsibility for teaching others some of the operations you have mastered. The shop supervisor will save time if he has you share the knowledge and skill you have gained. Of course he should "keep an eye on you" to insure that you are properly conducting the training.

1-9. Supervisory duties and responsibilities of the 5-level sheet metal specialist from Specialty Training Standard 53330/50/70 are listed in the following paragraphs.

1-10. *Plans and schedules work activities.* The sheet metal specialist:

- Plans workload schedules and makes work assignments.
- Establishes production control standards.
- Plans and improves work methods and procedures.
- Assists in executing unit property records.

1-11. *Supervises personnel.* The sheet metal specialist:

- Supervises sheet metal fabrication and repair operations.
- Applies principles of personnel management.

1-12. *Establishes and conducts on-the-job training.* The sheet metal specialist:

- Indoctrinates newly assigned personnel concerning local operating procedures, regulations, and methods.
- Reviews status of on-the-job training for adequacy and adherence to established objectives.
- Determines on-the-job training requirements and provides for additional training where required.
- Assigns on-the-job training responsibilities.
- Maintains on-the-job training records.
- Insures that all personnel are familiar with applicable directives.

1-13. *Inspects and evaluates activities.* The sheet metal specialist:

- Inspects the sheet metal shop for compliance with policies and regulations.
- Inspects for proper maintenance of tools, machines, and equipment.
- Checks for proper storage and use of supplies and materials.
- Inspects work areas for safety and fire hazards.
- Examines work orders for proper authorization.
- Insures timely completion of priority assignments.
- Stamps or tags work to indicate status.
- Coordinates work requirements or rejections with personnel concerned.
- Interprets inspection findings and makes recommendations regarding corrective actions.

1-14. **Sheet Metal Technicion, AFSC 53370.** The supervisor of the sheet metal shop may be a military sheet metal supervisor or a civilian foreman. The duties of each are similar and often include supervision of the welding shop as well as the sheet metal shop. The duties and responsibilities from the specialty description for AFSC 53370 in AFM 39–1 are listed in the following paragraphs. The 7-level sheet metal technician must thoroughly understand supervisory principles and be able to apply them to operational situations.

1-15. *Plans and schedules work of sheet metal activities.* The sheet metal shop supervisor:

- Plans workloads and procedures and schedules the work assignments.
- Establishes work assignments and work control standards.
- Prepares and analyzes reports, tables, and graphs pertinent to such factors as man-hours utilization, job time-rates, and material waste.
- Improves work methods and procedures for better utilization of personnel and increased economy of operation.
- Times recurring operations to establish standard job time-rates.
- Stimulates and maintains good morale.
- Regulates use of space, equipment, and supplies.
- Analyzes abnormal use of supplies and materials and promotes use of shop residue.
- Designs organizational structure to delineate lines of authority and to place specific responsibilities.

1-16. *Supervises sheet metal personnel.* The sheet metal shop supervisor:

- Checks sheet metal operations for correct selection of material and accuracy of sheet metal layout.
- Observes sheet metal cutting, drilling, punching, forming, bending, and refinishing for adherence to approved procedures.
- Checks use and maintenance of various sheet metal cutting, bending, and forming machines for compliance with approved methods.
- Assigns tasks to individual workers. Maintains followup to insure adherence to assigned priorities and to determine current status of completion.
- Reviews in-progress and completed work to verify conformance with drawings, specifications, and established work standards.
- Insures adherence to established safety rules.
- Prepares performance ratings, schedules routine leaves, controls shop duty adjustments, and accomplishes other personnel actions.

- Coordinates work schedules with other affected shops and activities.

1-17. *Establishes and conducts on-the-job training for sheet metal personnel.* The sheet metal shop supervisor:

- Orients and adjusts newly assigned personnel within the shop.
- Conducts and coordinates on-the-job training and group meetings.
- Determines requirements for training from observation of work procedures and inspection of completed work items.
- Isolates training requirements to individuals and small groups and provides for additional on-the-job training where required.
- Records training accomplished and individual progress.
- Assigns on-the-job training phases to senior workers and makes followup after completion of training to determine adequacy and effectiveness of instruction.
- Insures that all workers are familiar with applicable directives.

1-18. *Inspects and evaluates sheet metal activities.* The sheet metal shop supervisor:

- Periodically inspects shops to determine status of compliance with policies and regulations.
- Checks for proper maintenance of machines and equipment, storage and use of supplies and materials, and presence of fire and safety hazards.
- Reviews supply and equipment requisitions and maintains followup to determine receipt of ordered or suitable substitute items.
- Examines work orders for proper authorization. Checks materials list. Compares time in shop with priority assignment.
- Inspects completed work for conformance to drawings, specifications, and established work standards.
- Discusses findings of inspections with responsible supervisor or superintendent and makes recommendations regarding corrective action.
- Tags work to indicate status and releases work from shop.

1-19. *Performs technical sheet metal functions.* The sheet metal shop supervisor:

- Reviews sheet metal construction requirements and develops procedures for accomplishing work.
- Makes decisions with regard to material substitutions and alteration of drawings or specifications.
- Adapts directives and policies of higher authority to shop routine.
- Performs trial sheet metal fabrication operations during periods of peak workloads or personnel shortages.
- Fabricates heating and ventilating ducts, guttering, downspouting, roof flashing, food service equipment, canopies, and miscellaneous containers.
- Repairs and installs sheet metal heating and ventilating ducts, roofing, guttering, or fixed utility equipment.

1-20. **Metalworking Superintendent, AFSC 53690.** The metalworking superintendent manages activities engaged in testing, fabricating, repairing, and machining metals and metal products; corrosion control in missile, aircraft, and support system equipment; and nondestructive inspection of aerospace material parts, components, and pressurized systems. Although the superintendent may be civilian or military, the duties are similar. The duties and responsibilities from the specialty description for AFSC 53690 are listed in the following paragraphs.

1-21. *Plans and organizes metalworking activities.* The metalworking superintendent:

- Plans workloads and work assignments among various shop units such as machine shop, welding shop, heat-treating unit, electroplating unit, sheet metal shop, aircraft structural repair section, corrosion control activity, and nondestructive inspection activity.
- Establishes overall metalworking activity production controls and work standards.
- Prepares and analyzes reports and graphs indicative of such factors as production capability, actual production, and work backlog; production man-hours and overhead man-hours; percentage of rework requirements or rejects; on-the-job training progress; and operating costs.
- Prepares and distributes comparative studies of achievement by shops, units, and sections to inspire interunit competition for improved production and quality.
- Develops and institutes procedures for improvement of work methods.
- Works out improvement in design or use of tools and equipment.
- Develops and establishes production line methods for the most efficient operation.
- Establishes requirements and distributes equipment and supplies in accordance with mission and workload of individual shop units.
- Develops organizational charts to establish definite lines of authority and to assign specific responsibilities.
- Assigns personnel to shop units in accordance with workloads and makes intraunit personnel reassignments.

1-22. *Directs metalworking activities.* The metalworking superintendent:

- Observes metal cutting, forming, and assembly operations for general conformance with approved shop procedure.
- Directs proper use, maintenance, and repair of metalworking, corrosion control, and nondestructive inspection machinery, tools, and equipment.
- Assigns work and work priorities.
- Expedites work program in order to meet estimated man-hour requirements and completion dates.
- Advises higher echelon and interested activities of current status of work progress and expected date of completion.
- Confers with supervisors regarding production delays, inaccurate man-hour estimates, and excessive job time-rates, and approves corrective action to be taken.
- Makes followup of back-ordered materials for work orders.
- Directs proper storage and use of bench stocks subject to waste and misuse to effect maximum conservation.
- Provides for safekeeping of tools and equipment.
- Provides for proper lighting and ventilation of shop areas, establishment and enforcement of required shop safety rules and devices, and general cleanliness and orderliness of shop areas.
- Makes recommendations on personnel actions such as reclassification, grade adjustment, and discipline.
- Promotes harmonious relationship among immediate assistants and maintains high morale of workers by such actions as personal interviews, adjustments to time schedules, and organization of off-duty group recreation.
- Rates subordinates for efficiency, reviews ratings made by supervisor, and recommends promotions.
- Schedules routine leaves of absence and accomplishes other personnel actions.
- Coordinates work schedules with other activities such as missile and aircraft maintenance, communications maintenance, air installations, and food service.
- Prepares correspondence and maintains administrative correspondence files.

1-23. *Establishes and conducts on-the-job training for metalworking personnel.* The metalworking superintendent:

- Directs continuous program of organized on-the-job training for supervisors, technicians, machinists, welders, sheet metalworkers, aircraft structural repairmen, corrosion control specialists, and nondestructive inspection personnel.
- Directs breakdown of jobs into separate knowledge items and skills and makes periodic review of training charts to determine status of participation and completion of on-the-job training.
- Evaluates effectiveness of on-the-job training by observation of work performance, written or oral examination, or by comparison between current and past operational data. Alerts supervisors to future training requirements.
- Arranges for attendance of selected metalworking personnel at off-base or formal courses of related instruction. Conducts group meetings and familiarizes personnel with new or changed policies affecting shop operation.

1-24. *Inspects and evaluates metalworking activities.* The metalworking superintendent:

- Periodically inspects shops, units, and sections to determine status of compliance with directives governing shop administration and operation. Arranges special inspections to determine factors such as time compliance with modification directives.
- Directs and coordinates inspectional duties performed by assisting technicians. Establishes and enforces adherence to quality standards for inspection and release of completed work items.
- Reports major deficiencies and outstanding accomplishments to higher authority.
- Follows up instructions given subordinates to determine sufficiency of corrective actions.

1-25. *Performs technical metalworking functions.* The metalworking superintendent:

- Tests new equipment and proposes improvements on standard metalworking procedures.
- Operates metalworking machinery in fabricating new metal parts or reworking reparable components.
- Resolves problems involving major repairs or large volume fabrication.
- Makes decisions on such matters as practicability and economy of parts repair or manufacture, corrosion control, nondestructive inspections, necessity for condemnation, material substitutions, and departures from standard work procedure.
- Establishes and revises shop procedures to conform to directives received from higher authority.

2. Promoting Harmonious Relationships and Resolving Personnel Problems

2-1. A leader is a person who leads, guides, directs, or commands the efforts of one or more people in getting a job done. He is supervisor and manager as well. Not only does he lay out the details of a job and assign and advise workers, but in many cases he has to assembly equipment and materials. Further, he must account for the time of the workers and the materials they use. You will find that effective management and leadership create a willing, cooperative, progressive, and continuously improving work force. These two important elements also develop a work force that is purposeful, skilled, trained, and smooth in operation.

2-2. **Personality Traits of a Leader.** Very few of us are leaders in all situations. Actually, most of us spend more time being led than leading. If you expect to accomplish a worthwhile job of supervision, you will start acquiring the traits that you most admire in leaders. We will start you off with the following list, which is by no means complete. We expect you to make additions to it.

a. Friendliness. Be friendly toward the people who work for you, yet retain their respect for your ability and leadership. Don't be noticeably more friendly toward some people than others.

b. Initiative. Have the ability and willingness to start new projects. Enjoy your work, and project your enthusiasm to others.

c. Ability to make decisions. Be able to make decisions based upon careful reasoning. Be able to admit it when you don't know, however. Don't pretend to know an answer when you don't.

d. Interest in people. Have an interest in people—be able to listen sympathetically to their problems and make an effort to understand them.

e. Understanding. Realize that a person may not be at his best at all times and that trouble at home or outside worries can affect anyone's efficiency. Understand that your men are individuals.

f. Sincerity. Don't simulate friendliness and interest. Don't be a "hypocrite." Make complimentary comments only when you really mean them. Identify yourself with your men to the point that you will fight for them, even in their absence, provided they are in the right.

g. Pride in accomplishment. Have a sincere desire to see your men do good work—not fear that they will become as proficient as yourself. You should want your men to succeed, and be proud when they do. Don't be afraid of your position, your subordinates, tough jobs, or honest mistakes. Convey the impression that you are trying to work yourself out of a job and your men into it.

h. Patience and emotional control. Never assume that because a task is easy for you, it will also be easy for everyone else. Realize that the person to whom you must explain a task several times may later perform the job much better than the fast learner. Control your temper and think before you speak. A workman may hold a grudge a long time because of words spoken too hastily—and a worker with a grudge won't be as efficient. When necessary, give constructive criticism without losing your temper. When things go wrong on the job, appear calm and unperturbed—and do not get frustrated. Straighten out problems with as little fuss as possible.

i. Fairness. Don't deal out favors to those who feed your ego. Establish fair production standards; don't require one man to complete a big job in the same time that you give another man to complete a smaller job. When you evaluate a man, rate him on actual performance (production and quality) rather than upon his friendly overtures to you.

j. Personality. Personality is not what you have; it is what you do when you are with others. Success will come only when you have entirely forgotten yourself and instead become sensitive to others. Learn the art of forgetting yourself in a group. It isn't difficult; simply watch the other fellow and do what is appropriate. Think of each person as being a distinct individual whom you will try to understand and make a bit more happy. Perhaps the best rule of action is the Golden Rule: "Do unto others as you would have them do unto you."

2-3. **Basic Needs of People.** The fact that a worker may reach a satisfactory production level doesn't mean he is going to stay there without further attention. As you well know, many things cause a worker to "let down" in his performance. For apparently no reason, a worker may change overnight from a satisfactory, satisfied performer into an unhappy, low producer. One of the responsibilities of a supervisor is to find out what these reasons are and to help that worker on the way back to high performance. This is a difficult job because there are no hard and fast rules that work for everyone. Workers aren't like machines. You can't just push a button and make them do what you want them to. You can't just look at them and determine why they don't run right. Workers are people with ambitions that can be stirred, pride that can be hurt, nerves that can be shattered, and hopes that can be realized. This makes workers complex and difficult to understand, but you must understand them if you are to develop a satisfied, cooperative, and productive work force. To help you understand what makes people act as they do, it is necessary for you to know the basic needs of people: recognition, opportunity, security, and a feeling of belonging.

2-4. *Recognition.* Every person has a basic need that we call recognition. Each person has his own way of expressing this need, but nevertheless, it exists in all of us. Think about some of the things that happen to you that make you feel you are being recognized—receiving credit for what you do and praise for a job well done; being given the feeling, by attitude and actions of your supervisor, that what you do is important and contributes to the success of your organization; being allowed and encouraged to express your opinions in matters that affect you; receiving adequate pay for work done; and receiving the respect of your associates. Ask yourself, "Are these things important to me? Do I need to be satisfied and content in my job?" If you answer "Yes"—and almost everybody does—then recognition is one of your basic needs.

Other people need recognition, too; so when you are supervising a man, tell hom how he is doing, give him a pat on the back, keep him informed, give him special assignments, and when the time comes, consider him for promotion.

2-5. *Opportunity.* Opportunity is another one of our basic needs. The desire to improve our position and station is an important part of our job situation, but there are other types of opportunities which are important to workers, such as opportunity to do a good job, opportunity for greater professional development on the job, and opportunity to use their best abilities consistent with requirements.

2-6. *Security.* This is another basic need that workers must satisfy if they are to be content and adjusted to their job situation. We're not talking about security as it is related to safeguarding military information. The kind of security we're talking about is feeling that the boss trusts you to do a good job without looking over your shoulder all the time and the feeling that you can keep your job as long as you do it well. In general, we're talking about having a sense of well-being and satisfaction about your job, your family, your associates, and your friends. Just as in the case of the other basic needs, security doesn't mean the same thing to every person. Each of us has a somewhat different idea of security. To some, it is money in the bank; to others, it is a happy and secure home life; and to still others, it is a permanent job. Although security doesn't have the same meaning for everyone, each individual strives to attain the kind of security he needs.

2-7. *Belonging.* People are essentially social by nature. The entire history of mankind is made up of stories about people banding together for some common cause. Just driving into any medium-sized town will provide an example of this. Somewhere on the way into town you will probably find signs announcing the day of the meeting and the location of all sorts of civic and service clubs—Rotary, Kiwanis, Lions, and so on. None of these would exist if it weren't for the desire of men to belong to groups and to be identified with them. This desire to belong also exists in offices and workshops where there are a number of people. Looking further into a group of working people, we find informal groups or organizations. The informal organization develops out of common interests, likes, dislikes, and sentiments of people. People who enjoy the same sort of activities are usually drawn together because of the interest they share in these activities.

2-8. A supervisor must recognize that an informal organization exerts a very powerful influence over the productivity of his unit. Through the threat of losing status in the group, a worker can be influenced to adjust his production (either upward or downward). His attitude toward the "boss" can be affected—he doesn't dare to be friendly if the group he belongs to is hostile. In other words, whatever conduct the group considers appropriate is the type of conduct you can expect from each member. The wise supervisor learns to recognize the leaders of the informal groups and work through them; or even better, he is able to relate himself to the group and—through his leadership abilities—become both the leader of the informal group as well as leader in the shop (formal) organization. In any event, the challenge to the supervisor is that he must find a way to convince the informal organization that its needs can be met by achieving the goals of the formal organization.

2-9. **Individual Differences.** Although all of the basic needs we have just discussed are common to everyone, they are not present to the same degree in each individual. Some workers desire recognition above security; others want security more than anything else. For example, a young man, just out of school, may be more interested in opportunity for advancement than in security. An older worker with several children and a mortgage on the house will probably be more interested in security.

2-10. There are all sorts of differences in people—attitudes, abilities, aptitudes, interests, experience, emotions, education, religion, age, knowledge, skill, physical strength, and many others. What do these differences mean to you as a supervisor? Many things, but a few of them are as follows: They have a bearing on assignments; they have a bearing on growth potential; they have a bearing on the worker's stability; and they have a bearing on the way the worker acts and reacts.

2-11. Feelings of individuals are more often conditioned by emotion than by fact or logic. A supervisor cannot change the emotional nature of a worker, but through study of the individual and the situation he can learn how to help the worker adjust to a situation. Just as the basic needs of people seem to fall into four basic categories, *the differences also seem to fall into four different groupings*—mental, emotional, physical, and social.

2-12. Individual differences can affect the way you assign your work. If the work you want done requires heavy lifting, you would look for workers who are physically strong. If the work involves a lot of high pressure, you would try to get people who are emotionally stable. You wouldn't assign a person to a pattern development project if he was new and had very little experience in pattern development. Also, you usually try to take advantage of a person's formal education when it relates to the type of work he is doing. Here again we could go on and on, but these examples illustrate the importance of considering individual differences when assigning work to people or considering people for job assignments.

2-13. We mentioned how individual differences are important in making assignments and dealing with workers to satisfy their basic needs. The supervisor, then, has to work differently with each individual if a good job atmosphere is to be established. Thus, while dealing with workers resolves itself into recognizing and satisfying their job wants, it is not a simple task. Workers don't come to the supervisor and say "I want recognition," or "I want security," or "I want to be a part of the group." Rather, they reveal by their attitudes, emotions, and actions that these basic urges or desires are motivating them. They usually do this in a manner peculiar to their individual makeup, and the indications are varied and sometimes violent. When desires become thwarted, reactions result which should signal to the supervisor that something is wrong.

2-14. The supervisor must know his workers and their individual desires well enough to help them get job satisfaction. This is the key to good human relations. To guide worker actions, a supervisor must know enough about his people to be able to determine the approach he should use to get positive reactions. Good human relations are based upon friendly contact and understanding. An objective and orderly study of people and their actions is needed. It requires building techniques for dealing with people in terms of these understandings.

2-15. **Techniques of Good Human Relations.** We have seen that the basic needs we discussed—recognition, opportunity, security, and a feeling of belonging—are felt to a certain degree by all people. On this basis, we can therefore make a generalization to the effect that all people are alike. Yet we also found that people have definite physical, mental, emotional, and social differences. Again, we can generalize and say that no two people are alike. Taken separately, these statements about basic needs and individual differences seem to be true: yet when we put them together, they obviously contradict each other. What's wrong here?

2-16. Let's assume that both of the statements are true. Perhaps if we take them one at a time, we can arrive at some conclusions about people that will help a supervisor who is trying to establish good human relations among his workers. Examine the first statement, "people are alike." If this is true, we can see the possibility of the supervisor's developing certain techniques in dealing with workers—techniques which will apply to people in general and will assist him in his efforts to help his workers adjust to their jobs and form an integrated, cooperative work force.

2-17. *Let each worker know where he stands.* All workers need to know how they are getting along if they are to be happy and satisfied with their jobs. This includes whether they are doing a good job or not. How can we do this? We can take an interest in our workers and get to know each one personally. We can have periodic talks with each worker and see that each knows his job requirements. How often you contact your workers and how close the personal relationship should be will depend upon your individual work situations. There is a delicate balance between overfamiliarity and friendship. As a supervisor, you must walk the fine line of propriety or risk severe criticism, which can be very damaging to morale and productive output in your unit.

2-18. *Give credit when due.* This is another technique to guide the supervisor in his job relations with his workers. We know this is a good one. Experience has proven that this technique will get good results, and we know that the supervisor who ignores it will create problems that will cause lagging interest among the workers. But knowing the technique and knowing how to put it to use are two different things. Give credit when due is a good idea—but how do you do it? There are many ways. Here are some of them: Give a fellow a pat on the back and a little praise when he does a good job; use letters of appreciation and commendation; recommend outstanding performance ratings; use both the military and civilian suggestion programs which may give cash awards and other rewards for improvements developed by your people; and finally, let's not overlook the very important method of recommending personnel for promotion, upgrading, and better assignments.

2-19. *Inform workers in advance and let them participate in planning.* Supervisors can inform their workers of changes by personal contact with each individual, by written notices and bulletins, or by informal meetings and discussions. The latter is a good method, but just calling workers together in a meeting does not automatically win their support and approval of changes. The supervisor still has the problem of getting workers' interest and participation. He must do something to make the workers want to take part in planning for changes. He must encourage them to contribute their ideas and "pitch in" to meet the problems. It is the supervisor's attitude and conduct in general that make workers willing to cooperate.

2-20. *Gain the workers' confidence.* Some ways to achieve this are to take a personal interest in each worker; to be friendly, helpful, and fair in your dealings; to encourage the worker to come to you with his problems; and to take actions on the problems if at all possible.

2-21. We have discussed five ways of putting human relations techniques into practice. These are by no means all of the techniques that a supervisor will use. However, the five discussed are of

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major importance and, when used properly, will be of great assistance to a supervisor.

2-22. Although techniques are useful in dealing with people, they will fail if they are not used properly. Supervisors may know theories of handling people, but when it comes to dealing with individuals, more specific knowledge is required. The supervisor must get to know his workers and understand their particular difficulties and needs before he attempts to apply techniques. He must study the individual worker, learn his personal interests and problems, and know his reactions. It is just plain commonsense that satisfied workers will perform better than unhappy workers. We repeat: Your chances of having satisfied workers are greatly increased when you:

- Let each worker know where he stands
- Give credit when due
- Keep workers informed
- Encourage workers' participation
- Gain workers' confidence

2-23. These five techniques are essential in good human relations. The supervisor who develops them will get better performance from his workers. A supervisor who recognizes these techniques and applies them with an understanding of the individual needs of his workers is described as a worker-centered supervisor—the kind of person who most often earns the title of "leader." The opposite of this is the "driver," who is concerned only with production and who makes no effort to understand his workers. The big mistake which this type of supervisor makes is that he fails to recognize the importance of the individual when getting the work out. There is no doubt that he will get results and get the job done—but only to the limits accepted as minimum.

2-24. The worker-centered supervisor thinks of people first, is willing to sit down and talk with his people, coaches them and tells them in advance of changes, and gets their ideas on changes. This type of supervision is almost always by far the greater producer. The exceptions to this are few and usually owe their success to some unusual factor such as a work situation or personality. Motivation can be both negative (fear) and positive (reward). The production-centered supervisor has a tendency to favor negative motivation, whereas the worker-centered supervisor favors positive. Various studies indicate that positive techniques more often achieve desired results than negative techniques as far as work output and job satisfaction are concerned. This is not to say that a good supervisor is concerned only with making people happy; it is conceivable that a person who carried this to extremes would never get anything done. He could give everybody 3 days off every week and never accomplish anything, but all of his workers would be happy in that respect. So the worker-centered supervisor isn't one who forgets about the work to be done and just concerns himself with keeping people happy. Rather, he is one who relates the work to the individuals working under his supervision in a manner that wins their cooperation and support for the mission of the unit. A supervisor who builds good job relations can actually produce more than a supervisor who concentrates on production and attempts to drive his workers.

2-25. **Problem Solving.** Every day supervisors encounter problems that are new. If all of us were to go about solving problems in exactly the same manner, we would necessarily have the same thought processes. Although we do not think alike, all of those who are capable of finding proper solutions quickly and easily do have something in common. They follow a fairly well-established pattern of thought and action. There is no trick or magic formula for solving all problems, but those who are most successful follow an orderly, organized process such as the following:

- Define the problem
- Establish objectives
- Gather facts
- Weigh and decide
- Take action
- Evaluate the action

2-26. *Define the problem.* This is the first step in problem solving. When trouble arises, we say that we have a problem. But if someone asks us, "Just what is your problem?" we often find it is difficult to put into words. Yet if we cannot state the situation clearly, it is hard to know exactly what we want to accomplish. Defining our problem clearly leads us rather easily into setting objectives. For example, a supervisor may be faced with what seems to be clearly a problem of absenteeism. However, further study of the situation may reveal that the real problem is transportation, housing, epidemic influenza, or even the World Series. A high percentage of spoiled work could represent a problem of forced machine speeds, poor material, lack of training, or a number of less obvious reasons.

2-27. *Establish objectives.* To determine objectives, we need to know the whole story. We can do this only by securing as much information as is possible in the time available. It is poor management to risk a decision without sufficient facts. Granted, there are times when a decision must be made on the spur of the moment because of pressures of time. But even then, every possible attempt should be made to get all the information that should be known before the decision is made.

2-28. *Gather facts.* There are a number of sources from which information can be obtained—records, rules, regulations, and customs that are applicable. Workers who are concerned with the problem may very well be better informed about it than the supervisor; it may be as important to get their opinions and feelings as it is to get the facts. The supervisor can gain information by listening to workers talk about the situation; keeping his eyes open and observing what is happening; reviewing records and policies; asking questions; and, if practicable, delegating the gathering of facts to an understudy.

2-29. One question that may seem puzzling is this: "How can a person tell when he has all the significant information or at least enough to solve the problem?" Perhaps the best guidance in answer to this question is that, as we consider the facts, they begin to fit together to form a pattern. If the picture they form has missing pieces, it must be that some facts are missing. Maybe a second, closer scrutiny will uncover them. On the other hand, if they add up to the answer, we need look no further. However, if you have some important facts left over that do not seem to fit in, maybe your diagnosis is wrong. Before you discard the facts as irrelevant, it is important that you really think about them. Sometimes important solutions, even new discoveries, are made by a person who can find the relationship between facts that others have passed over as unimportant.

2-30. *Weigh and decide.* What we have been saying is that, after we get the information, we have to fit the facts together and consider their bearing on each other. We can help clarify their relationship to each other by asking ourselves questions such as: What caused this to happen? Who was responsible there? Did this happen before or after that? Soon the facts will fit together like a jigsaw puzzle to form a clear picture. As you think about the problem and analyze the facts, possible solutions naturally will occur to you. You should list every reasonable solution for careful review later. As you do this, you will be most interested in checking the anticipated results of each possible action to determine the probable effect on individuals, groups, production, and so on.

2-31. This process enables you to select the best action to take, because you will be able to identify that action which will best accomplish the purpose. You will remember that the purpose was stated in the objective. Other considerations of what action to take might relate to time, money, equipment, supplies, and other resources.

2-32. *Take action.* Up to this point, we have discussed ways to make a sound decision, but we cannot leave it here. All the effort and time spent in arriving at this decision is wasted if favorable action does not result. A responsible official who delays or otherwise fails to take action which has been decided upon is avoiding his responsibility and may be showing a form of weakness. When taking final action on a problem we have to consider these questions: Should I handle this myself? Do I need help in handling it? When and where should final action be taken?

2-33. *Evaluate the action.* The best laid plans and the most carefully made decisions sometimes do not work out exactly as anticipated. Many times we just cannot get all the pertinent facts in the time available. Or it may be that some of the facts on which we based our judgment are false or misleading. Therefore, it is essential that we check on how the action is working out. Obviously, it is better to find out for ourselves that it is not working out and to make the correction ourselves rather than wait for the boss to find out. We should be the first to know it, acknowledge it, and correct it. After all, we're only human and we all make mistakes.

2-34. **Resolving Personal Problems.** There are workers with problems, and there are problem workers. Good supervisors are able to distinguish between the two. This ability is a fundamental requirement for effective supervision, because entirely different approaches are necessary to correct the two situations.

2-35. *Workers with problems.* Workers with problems may need assistance from the supervisor or from some other qualified person. Perhaps it is unfortunate that people are unable to keep their problems from affecting their work, but few can. Therefore, the more of their problems you resolve or help resolve, the less these problems will interfere with their work. Such problems do not normally follow a particular pattern and, therefore, each one must receive special attention.

2-36. *Problem workers.* The problem worker belongs to an entirely different category. This individual is one who fails to respond to efforts to help him; actually, he does not want help. He not only causes trouble for himself, but through his actions, or lack of action perhaps, he may disrupt others who are trying to do a good job. Corrective measures must be taken. A regulatory system has been established to assist you in handling severe cases.

2-37. One word of caution may be in order at this point. It is relatively simple for a supervisor to attempt to cover his own weakness by classifying as misfits anyone who objects to thoughtless misdirection. If the supervisor attempts to deal with such workers as he would a true misfit, he will encourage low morale and resentment.

2-38. It is fairly obvious that a good supervisor should deal firmly with problem workers; but at the same time, if the problems are to be solved, action could best be directed at causes rather than at people. Whenever you must deal with severe problems involving people, always ask yourself whether you are trying to fix the mistake or fix the blame.

2-39. You have to recognize that some people will cause difficulties no matter how conscientiously you apply the various techniques of good human relations. But this doesn't mean that the application of these techniques isn't worthwhile, because proper application will reduce the frequency and type of difficulties you encounter.

2-40. There may be problems you cannot solve without the help of your chief. There may be others you cannot solve without the help of some staff agency, such as the personnel office. You can solve problems within the scope of your authority without outside help. Those beyond your authority must be referred, through formal channels, to higher authority for action. But by far the best procedure is to handle dissatisfactions before they get into formal channels. In other words, you're concerned with how you can stop trouble in the early stages before it gets out of hand.

2-41. *Discussing problems.* Since a worker's problems are also the supervisor's problems, let's discuss how to handle them. You can use the systematic problem-solving techniques. When a worker shows symptoms of being in trouble, you may need to talk to him to find out what is wrong. Be sure to gather available information before the talk, talk in a private place, be a good listener, base the discussion on facts, and follow up.

2-42. It is easy to see how these factors are important. Since the purpose of talking to him is to get his story, the necessity of letting him do most of the talking is obvious. When he tells his story, it may help for you to restate his problem just to be sure you understand the situation. This is very often an effective way to help the person clarify the problem in his own mind. You may also ask for clarification on some points which may cause the person to change the description of the problem. The process of restating the problem will sometimes suggest a solution. At least he feels better when he "gets it off his chest." By listening, the supervisor has gathered valuable facts and, in addition, may put the complaining worker in a better frame of mind.

2-43. The nature of the complaint will suggest whether it must be investigated further, whether you can handle it yourself, or whether it must be referred to someone else. We often find that many of the dissatisfactions of workers are relatively small problems with solutions that aren't too difficult. But even little problems will grow into greater problems if they are mishandled or ignored. A dissatisfied or disgruntled worker finds fault with many things. Also, he may stir up trouble among other workers.

2-44. This points out the necessity of trying to stop trouble in its early stages. This sometimes is difficult to do unless you are very alert and have actually studied the individual differences in your workers. Also, you must maintain a good relationship with each worker to be sure that he isn't afraid to discuss his problems with you. If a supervisor has earned the workers' confidence, they will come to him with their problems. This is a true test of the confidence that they place in him. There are many cases on record where a worker has trouble off the job that he either consciously or unconsciously transfers to the job. Sometimes the supervisor's first indication of difficulty is when the worker makes a complaint. In such cases, it is rather apparent that the supervisor may not have gained the confidence of his workers.

3. Supervising Shop Personnel

3-1. As a worker in the sheet metal shop, you use tools, machines, and equipment to repair, fabricate, and install sheet metal components. The result of your work are immediate and tangible, and at the end of a given period you can look at and measure the products you have turned out.

3-2. As a supervisor, you will find it a different story. Your work output will be measured in terms of what your workers do, rather than what you do personally. You must get your work done through others. This puts you in the position of being responsible not only for what you do individually but also for what your workers do. In this section we are going to discuss some of the ways to get production out of the workers. Let's begin with what a supervisor should do with a man who has just been assigned to the shop.

3-3. **Orienting New Personnel.** When a new man is assigned to the shop (or any organization), he should be introduced to the job and the people with whom he will be working. This introduction is called an orientation. It is one of the most important responsibilities of the supervisor, because this is when the new worker gets his first impression of the new assignment. The impression may be good or it may be bad, depending on how well the supervisor conducts the orientation. The effects of a bad orientation will take a long time to correct. whereas a good orientation will satisfy the four basic needs of people which we discussed earlier in this chapter—recognition, opportunity, security, and a feeling of belonging.

3-4. When a new worker reports for duty, remember that the orientation can be a distinct motivating factor because it can convince him that he has found a good job in an interesting and important place to work. Before you begin the actual orientation, introduce yourself; then guide the conversation along personal lines something like the following:

a. Get his name correctly; then remember and use it as you proceed with the interview.

b. Find out his marital status—then (if applicable) the number, age, and sex of his children.

c. Inquire about *his* age.

d. Ask about his education and experience and his special training and talents.

e. Check on his hobbies and interests.

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f. Find out about his home background. (You may have mutual interests—or someone already working in the shop may be from the same locality.)

g. Find out where he is living. If he is living off base, offer to help him find a car pool or satisfactory transportation to work.

h. For each bit of information you get from him, try to give him a little in return, not only about yourself, but about the men with whom he is going to work.

3-5. After you have obtained personal information, you will know better how to orient the new worker. Among the "official" things about which you must tell him (after requesting that he ask questions when he wants further clarification) are the following:

- The functions and organization structure of your shop.
- Where his position fits into the organizational structure, and the importance of his position.
- The supervisory chain of command and the person to whom he is directly responsible.
- Duties and responsibilities for his position and the opportunities for advancement.
- The concepts of career development and its relationship to the career program.
- The duties (from the specialty description and specialty training standard) that he will learn to perform in this assignment.
- The standard of work required.
- Specific shop procedures and policies (duty hours, special details, special meetings to be attended, etc.).

3-6. Finally, introduce him to the other shop personnel. As you walk around, point out items of interest—particularly those that will specifically relate to his first job. It is best not to burden him with a lot of small details that he won't understand. Leave the small details for him to learn when he actually starts doing the tasks. During the walk, introduce him, not as a new man, but as a person of interest by finding something to say about his qualifications or interests. Take special pains to introduce him to men who may come from the same part of the country or who may know the same people. Introduce and turn him over to the person who will be directly responsible for his training.

3-7. During the following days and weeks as he trains on the job and works the exercises of his career development course, be sure to give him any assistance needed, let him know how he is getting along, give credit when due, and gain his confidence. Learn all you can about his emotional stability and reactions so you can quickly solve or bypass any problems that might have a bad effect on his work. Don't forget what you have learned about the basic needs of people, individual differences of people, techniques of good human relations, and problem-solving methods.

3-8. **Directing Work.** Directing work is the vital activity between preparation and actual operation. It consists of issuing instructions or otherwise indicating to subordinates what to do and how and when to do it. Desired performance depends upon mutual understanding of the directions between the workers and the supervisor. This understanding is frequently difficult to achieve because the directions may have one meaning to the supervisor and another to the worker.

3-9. *Two-way process*. When giving work directions, you should know your subordinates' capabilities and their workloads. Equipment, material, or supplies needed to accomplish the work directions should also be considered. Much time may be lost, and workers may become disgruntled when a supervisor fails to consider workload or facilities at the time he gives the directions. You can probably recall many examples of poorly planned orders. In each case it is evident that the supervisor must insure that his workers understand the directions if the desired job performance is to be attained. When you give an order, you need to know whether it has been understood. If the worker does not understand, or if he has any questions, he should let you know. This interchange of thought and information should lead to a better understanding and appreciation of the situation involved, for you as well as for the worker. Thus, we see that good directing of work is a two-way process, resulting in improved performance and harmonious relations. In the absence of this two-way process, confusion and irritation develop.

3-10. It is the responsibility of the person giving the directions to make sure that they are clearly understood. A good technique to help you make sure the directions you give are understood is to ask the worker to repeat your instructions by telling you what he's going to do. Also be sure to ask the worker if he has any questions.

3-11. Through the use of the two-way process in directing, we insure that the worker knows and understands. We eliminate confusion and lost man-hours, and direct the worker's efforts toward the objectives to be accomplished. Through good directing we are able to get maximum use of our workers.

3-12. *Giving good directions*. Now that we understand that directing is a two-way process, let's look into the characteristics of giving good work directions. The framework for a large number of our directions is provided by directives that control, such as regulations, manuals, and operating instructions. These controlling directives should be used as guides when you prepare work directions for workers. However, there are situations that call

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for decisions and directions that are not covered by any directives you already have. In these cases you must issue your own directives, using your organizational objectives and good judgment as guides.

3-13. Of course, directions to workers will vary in different situations and with different workers. It may sometimes be necessary to demand immediate action, whereas in another situation, a mere suggestion of what is to be done will be satisfactory. For example, if you are giving directions to a newly assigned person, you would most likely use the request type of direction. Later you might decide to alter the type of direction you give that same person, according to his reaction. You may find that the demand or direct type of direction is necessary to motivate this particular person to action; on the other hand, it may be necessary only to suggest what you want done to achieve the best performance from him.

3-14. With experienced workers who have willing, cooperative attitudes you would probably get the results you want with a suggested or implied direction or by asking for a volunteer. With experienced workers, the demand type of direction will often cause worker resentment, tense relations, and worker dissatisfaction if used unnecessarily when a suggestion would have accomplished the desired results.

3-15. *Oral and written directions.* Worker reaction is determined to a great extent by the manner in which your directions are given. Directions may be expressed orally or in writing. Each method has its advantages. For example, it is foolish to give short, simple directions in writing or to give long, complicated directions orally.

3-16. It may sometimes be desirable to give an oral direction to supplement a written direction. This may be necessary when you wish to stimulate interest by explaining why or when you wish to afford an opportunity for questions. When issuing a new operating instruction, rule, or directive to your workers, it is sometimes wise to supplement these with oral explanations so that you can be sure the new directive is fully understood.

3-17. When issuing directions, you can check on the adequacy and eliminate possible confusion or misunderstanding by using the management tools of "What? Why? When? Where? Who? How?" If all of these questions are answered in the directions you give, the possibility of misunderstanding is vastly reduced.

3-18. Sometimes even when all of these questions are answered, the directions are still not fully effective. For example, oral directions may not be understood because you assume that the worker has a full knowledge of the subject, you use words that are too technical or too complex, you are not specific, or you include too much information.

3-19. Likewise, a written direction can be misunderstood. For example, it may contain answers to the six questions and still be too lengthy, too complicated, arranged in an illogical sequence, make work appear unduly complicated, or lack needed authority. We must therefore not only be certain that all of the needed information is included but also must check the language and feasibility of our directions.

3-20. *Attitude of the director.* Now that we have discussed how to insure that our directions are complete, let's consider the attitude of the individual who gives the directions. Perhaps you have seen a supervisor give an order in words but suggest, by his attitude, that the order is unimportant. For example: "The chief wants us to count all those parts in the bench stock again. Take care of it as quickly as you can, will you, so that we can get at something worthwhile. Here's a copy of the count we made last week, if you want it!"

3-21. It isn't hard to picture the attitude of the workers assigned to this job. If their supervisor thinks it's a waste of time, it stands to reason that the workers will lose interest in their jobs and perform the work in a careless manner. We must believe in the importance of the work we are doing if we are going to do it well and enjoy doing it. We must feel that the directions we give are important if we expect our workers to do their jobs well and enjoy doing them. Sometimes we must assume that the chief knows more than we do, perhaps even more than he can tell us.

3-22. **Rotation of Duty Assignments.** Most Air Force sheet metal shops are rather small (4 to 8 men), so rotation of duty assignments is not difficult for the supervisors. Rotation of duty assignments as it is practiced in larger shops and organizations is not necessary in most sheet meta. shops. although there are exceptions, such as paperwork and truck driving. By paperwork we mean such duties as logging work orders, taking service calls, checking and logging man-hour reporting cards, and checking preventive maintenance records.

3-23. The supervisor or foreman who asigns men to assist in these paperwork duties will be fulfilling some of the supervisory and management requirements for 5- and 7-level trainees, and at the same time will be training assistants who can help free him from spending so much time in the office. This will give him more opportunity to supervise fabrication, installation, and repair jobs. Whether or not he assigns subordinates to assist with paperwork will usually be influenced by the number of men who are training on the job for the 5 and 7 skill levels. For example, think of yourself. You are now studying the supervision and management portion of CDC 53350. It is important that the work assignments you make to others parallel (as much as possible) the material you are studying. However, if no one in the shop is on 5- or 7-level

OJT, the supervisor or foreman should rotate all workers so that each can learn to assist with the paperwork.

3-24. The other duty rotation that may occur in the average sheet metal shop is truck driving. You will find it helpful to have each sheet metalworker qualified as a vehicle operator; then set up a rotation roster for the duty. Some supervisors find that a weekly rotation cycle is a workable practice. Thus, one man, for a week at a time, will be responsible for obtaining a truck from the civil engineer subpool, using it for jobs and errands during the day, and returning it to the subpool at the end of the day. Another rotation plan used by some supervisors is to assign the crew leader (who may have more than one crew) to drive the truck. This plan will allow the crew leader to go freely from one job site to another and run the errands necessary for each crew.

3-25. Other than these exceptions (paperwork and truck driving), most of the duty assignments in the shop are controlled by work orders, and each crew will probably perform a complete job. Usually the same crew will stay with a job from patternmaking through installation. Thus each man performs a variety of assignments and is not confined to a single operation, as might occur in a large shop or organization.

3-26. **Performance Requirements.** Just as you feel that you have a right to know exactly what your supervisor expects from you, so do your workers have that right. You also believe you should be told how your work will be judged. Those whom you supervise are no different; they, too, want to know what their job is and how you will go about judging their performance. Both you and your subordinates are seeking performance requirements. An example of performance requirements is shown in figure 1. Notice that each task is followed by the requirements which have been determined to be acceptable for the task. Notice also that the performance requirements fulfill a function not done by the Specialty Training Standard—*quantity of results in a given time, quality of results in terms of how well the job must be performed, and manner of performance*. Actually, a performance requirement is just a fancy term for a description of what constitutes a job satisfactorily done.

3-27. *Determining performance requirements.* The approach to determining performance requirements should be realistic and practical. Frequently we have difficulty in setting requirements because we overemphasize operating details of the job rather than the results we expect. Our objective is to require the results which the job must achieve so that the mission of our unit will be accomplished. By setting the requirements at a reasonable level, we stimulate people to work. These individuals are neither overloaded nor underloaded. We put within their reach, through a safe workload, the satisfaction of a job well done. From your own experience you have probably seen what happens when workers are overloaded. Some of these results are accidents, errors, fatigue, high turnover of personnel, resentment, and slowdown. Conversely, the situation is also bad when workers don't have enough to do. The results here are usually mischief, excessive cost of operations, grievances, and absenteeism. These factors of overload and underload of workers are important when determining the level of performance requirements. Our decision often determines whether we get the results that we expect.

3-28. Performance requirements for each work operation must describe acceptable performance. They should be set at a level of performance which can be fairly expected of any qualified, competent worker who may be assigned to that position. It is generally true that workers will become frustrated and quit trying to reach a goal if it is set too high. The requirement must be at level attainable by average workers. Also, there should be room for the exceptional workers to perform above the requirement.

3-29. In this respect, you can readily see the dangers of setting a requirement based only upon the level attained by the worker now assigned to the position. This assumes that the worker is meeting all the requirements of the position in exactly an acceptable manner. If the position is filled by a person of unusually high qualification, it penalizes the worker by rating his outstanding performance as only satisfactory. In the same situation it would penalize future workers who were competent but not outstanding by rating their performance as unsatisfactory or unacceptable. If the worker's performance is actually inadequate but is used as the basis for writing performance requirements, the level of satisfactory performance will be too low.

3-30. Another factor which must be taken into consideration when writing performance requirements is the fact that all workers do not produce the same amount and quality of work. Rather, there is a certain range of performance which is considered acceptable: for example in figure 1, not more than 1½ hours to fabricate a vent cap. Performance below this level would be considered below average and possibly unacceptable. Performance exceeding this level would be considered above average and possibly outstanding. This range should also be realistic.

3-31. Each supervisor must make certain that the worker understands fully what is expected in his job. The following procedures can be used for determining performance requirements:

a. Select the task or major work factors of the job.

b. Decide tentatively what is reasonable to expect as to

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TASK	REQUIREMENTS
1. Fabricate single wall stack assembly such as that shown in figure 16. Develop, cut out, fold, and assemble sheet metal patterns.	Completed components should reflect good workmanship in pattern development, cutting, forming, seaming, and assembly.
a. Straight joints of round pipe.	Time required should not be greater than 1/2 hour per joint, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.
b. Ceiling thimble and double wall thimble.	Time required should not be greater than 1 1/4 hours per thimble, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.
c. Roof jack.	Time required should not be greater than 1 1/2 hours, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.
d. Storm collar.	Time required should not be greater than 1 hour, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.
e. Vent cap.	Time required should not be greater than 1 1/2 hours, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.

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Figure 1. Example of performance requirements.

TASK	REQUIREMENTS	PERFORMANCE
1. Fabricate single wall stack assembly such as that shown in figure 16. Develop, cut out, fold, and assemble sheet metal patterns.	Completed components should reflect good workmanship in pattern development, cutting, forming, seaming, and assembly.	
a. Straight joints of round pipe.	Time required should not be greater than 1/2 hour per joint, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.	Completed patterns and fabrication of 2 joints in 1 hour. Workmanship satisfactory, dimensions within specified tolerance, and no supervision needed.
b. Ceiling thimble and double wall thimble.	Time required should not be greater than 1 1/4 hours per thimble, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.	Obtained factory-made ceiling thimble. Completed patterns and fabrication of double wall thimble in 1 hour. Workmanship satisfactory, dimensions within specified tolerance, and less than 20% supervision given.
c. Roof jack.	Time required should not be greater than 1 1/2 hours, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.	Completed pattern and fabrication of roof jack in 2 1/2 hours. Workmanship satisfactory and dimensions within specified tolerance. Required 1 hour of supervision to correct mistake in pattern development.
d. Storm collar.	Time required should not be greater than 1 hour, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.	Completed pattern and fabrication of storm collar in 1 hour. Workmanship satisfactory, dimensions within specified tolerance, and no supervision needed.
e. Vent cap.	Time required should not be greater than 1 1/2 hours, dimensions should be within 1/16-inch tolerance, and supervisory assistance should not exceed 20% of the task time.	Completed patterns and fabrication of vent cap in 1 1/2 hours. Workmanship satisfactory, dimensions within specified tolerance, and less than 20% supervision given.

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Figure 2. Example of a performance requirements rating chart.

(1) Quantity of results in a given time.

(2) Quality of results in terms of how well the job must be performed.

(3) Manner of performance.

c. Discuss the tentative requirements with:

(1) Workers assigned to the job.

(2) Your supervisors.

(3) Other supervisors determining requirements for the same type of operations.

d. Check for possible effect of existing requirements:

(1) Trade or craft requirements.

(2) Management data.

(3) Requirements of higher echelons.

e. Review and formulate firm requirements to reach full understanding by workers affected.

3-32. *Using performance requirements.* Just as with all the other tools of management, simply developing a set of performance requirements and placing them in a neat file is almost the same as doing nothing. They must be used to be of any benefit. The supervisor must weigh the worker's performance continually against the requirement and discuss it with him periodically. He must then take action consistent with the worker's performance by (1) giving recognition to workers exceeding requirements, (2) helping workers who are below requirements by training or other appropriate means, and (3) motivating workers who are doing acceptable work to get them to perform better if they are capable.

3-33. There are a number of distinct benefits that the supervisor can realize from proper development and use of performance requirements. It can aid in production by establishing minimum acceptable production goals for each worker. You will benefit because of a better attitude on the part of your workers toward the work situation and because better job satisfaction will be created, since the workers will know what and how much is expected of them. Other advantages the supervisor can expect from the use of performance requirements are these: they create a sound basis for estimating future work capacity; they provide data for planning, organizing, and assigning work; they provide a basis for determining who needs additional training and how much is needed; they provide a sound basis for personnel actions and formal ratings.

3-34. Figure 2 shows one way that performance requirements can be made into a rating chart (which is sometimes called a performance standard). Notice how the chart makes column headings out of the tasks, requirements, and performance evaluations. The entries shown in the performance column are hypothetical and are used only to illustrate how a worker might have been rated by his supervisor.

3-35. **Evaluating Subordinate Personnel and Making Recommendations for Promotions.** You should become familiar with the items contained on the personnel rating forms, with the steps used in rating personnel, and with the items to consider when rating personnel. However, we should mention that, as a trainee for AFSC 53350, it will be unlikely that you will be required to evaluate personnel and make recommendations for promotions. Therefore, your experience will probably be limited to assisting your supervisor when he asks you about the workers whom you have trained in various parts of their OJT program.

3-36. First of all, a rating must be objective, not subjective. To explain these terms, an *objective rating* is impersonal, unprejudiced, and based on reasoning and actual facts. A *subjective rating* is formed on personal bias and prejudice. Thus you can see that the desirable type of rating should be objective. The rater (supervisor) must know what qualities are to be rated, must consider the worker's normal performance, must compare the worker's production and performance with that of other workers doing the same job, and must be sure that he does all of this objectively (not letting likes and dislikes influence him).

3-37. Different rating forms are used for airmen and civilians; however, both types are based on similar evaluation procedures. The performance requirements already discussed in this chapter can be used to determine how well a worker is performing assigned tasks. The review exercises (chapter and end of volume) in this CDC can be used to evaluate how much subject matter a worker has retained. The rating forms are designed to help supervisors determine the degree to which a worker meets the various requirements

3-38. *Airman performance reports.* Airman performance reports are made on AF Form 909, Airman Performance Report. This report must be made once a year, when the reporting official (NCO or civilian who is the immediate supervisor) changes, or for other designated reasons. Detailed instructions for filling out AF Form 909 are contained in AFM 39-62.

3-39. *Letters of evaluation for airmen.* There are recognized instances when the reporting offical (for AF Form 909) does not have the opportunity to observe directly a subordinate's performance and personal qualities. Under these circumstances, the reporting official may, if he so desires, a request a letter of evaluation from some designated person in the unit who is familiar with the duty performance of the ratee. The letter of evaluation should include as much pertinent information as is available. It will be prepared on AF Form 77a with the contents organized in the format suggested for Section VII of AF Form 909. The letter of evaluation may be used by the reporting official to aid in preparing the AF Form 909 or may be attached to the report.

3-40. *Civilian performance reports.* Although civilian performance reports are made on forms different from those for airmen, the evaluation procedures are similar. In both cases, performance requirements are recommended for evaluation of work performance. When a civilian is hired, he is assigned a satisfactory *entrance rating* by the civilian personnel office. During the first year of employment, which is a probationary or trial period, the civilian employee's performance must be evaluated by his supervisor. Following the trial period, the employee's performance must be rated annually (15th of May) by his supervisor. The annual rating should be discussed with the employee, and he should be given AF Form 671, Notice of Annual Performance Rating. The types of annual ratings include satisfactory performance, outstanding performance, and unsatisfactory performance. Although these ratings are given annually, the supervisor must continually make informal performance evaluations to determine if an employee's productivity is changing. For example, if production is decreasing, the supervisor should intestigate and determine the cause. This is a time when the supervisor should use the problem-solving techniques discussed earlier in this chapter. If production is increasing, the supervisor should recognize it quickly, determine the cause, and give credit where due. This should sound familiar to you because it is one of the techniques of good human relations.

3-41. Other types of civilian ratings include supervisory appraisals for promotion and pay increases. Promotion plans may provide for supervisory appraisals for promotions as a ranking, merit, or selection factor. Such appraisals frequently ask questions concerning employee skills, abilities, work habits, and working relationships which should be answered in light of continuous observation of the employee's performance.

3-47. When a civilian employee is eligible for a pay increase, the supervisor must determine, based on continuous evaluation, whether the employee's performance is of an acceptable level of competence to receive the periodic step increase. When any type of performance reports are made for a civilian, the supervisor should post the action to AF Form 971, Supervisor's Record of Employee. Any adverse action should be posted 90 days prior to the effective date.

3-43. **Scheduling Leave.** Leave schedules for shop personnel are needed by supervisors for advance planning of work activities and schedules. Proper planning makes the work easier and more pleasant for all concerned and can prevent friction, jealousy, and confusion. The proper use of resources (personnel, money, materials, space, and time) is an important part of a good plan; a good leave schedule can help make maximum use of shop personnel and time. The leave schedule for a shop can be as simple as the supervisor desires, as long as it shows each worker's name and when he will be on scheduled leave. Many supervisors like to have the leave schedule framed and hung on the wall in the shop office so they can refer to it easily when making work schedules.

3-44. The supervisor should try hard to satisfy each worker's leave preference because "leave when desired" helps morale. This can be accomplished by asking individual workers to submit written statements of the leave periods they desire. For civilians and military, the time for submitting leave periods is different. The civilian leave year runs according to the calendar year; therefore, the written statements of leave desired should be prepared in January. The military leave year runs according to the Government fiscal year, therefore, the written statement of leave desired should be prepared in July. These different leave periods do not prevent the shop supervisor from preparing a leave schedule for the shop. It just means that he must obtain the leave information at different times of the year.

3-45. When the worker's leave requests are turned in, the supervisor should study the requests to see if they interfere with normal operation or "rush periods" or if too many workers desire leave at the same time. The supervisor should discuss any conflicting requests (those that would cause the shop to be undermanned or that would hinder the accomplishment of the mission) with the workers concerned. Usually adjustments can be made that will satisfy each worker's leave preference.

CHAPTER 2

Supervision of Sheet Metal Fabrication and Repair Operations

This chapter has been prepared to help you gain a basic understanding of the supervisory principles and procedures which you should use when in charge of sheet metal fabrication and repair operations. When you become a crew leader or supervisor's assistant, you will supervise the performance of other workmen (trainees) in such things as checking pattern development, checking fabrication procedures, and inspecting completed items for accuracy and quality. The chapter is not designed to give you advanced training in supervision, because that is a part of 7-level training. However, the chapter will help you gain some of the supervisory knowledge needed to reach the 5 skill level.

4. Checking Accuracy of Pattern Development

4-1. Checking the accuracy of a pattern development is very important for many reasons. For example, if a pattern is incorrect, the entire component will be rejected, even if all cutting and forming operations are performed correctly. When you are supervising a job, you will need to keep a close check on the pattern development for use of the correct procedures, correct measurements,additions made in the right locations, and correct determination of the lengths of element lines.

4-2. Parallel Line Pattern Development. When checking parallel line pattern development for accuracy, remember that the element lines should be parallel and that the length of the element lines plays an important part in the correct layout of a component. Suppose that you are checking the accuracy of the elbow pattern shown in figure 3. First, see if the elbow in the elevation view is 90°. Check the radius and diameter measurements, then check the miter lines for correct location. Check that the half plan is the correct size, that element line points are in correct locations, and that the element lines are projected correctly to the miter line of piece I. Any mistakes you discover should be corrected. If there are no mistakes, check to insure that the pattern stretchout is of correct length and that element lines are an equal distance apart. Starting with element line number 1, check each line to see that it has been correctly transferred from the elevation view to the pattern. If any of these lines are too long, they will show up as high points on the pattern; if any are too short, they will show up as low points.

4-3. As you can see from the preceding example of changing a parallel line layout for accuracy, there are several things that can cause a defective component. For example, the incorrect location of the miter line (piece I) in the elevation view can cause the elbow to be more or less than 90°; or if the half plan is not divided correctly, the element lines will be located incorrectly. All of the steps in developing patterns are important; therefore, close supervision of inexperienced people is necessary.

4-4. Radial Line Pattern Development. Radial line pattern development is used to develop patterns for components with a base that can be inscribed in a circle and which have a vertex where all the sloping lines meet. In figure 4 we have included the layout for a truncated cone. You will find some similarity in checking radial line and parallel line layouts, such as finding the length of the element lines and transferring these lengths to the pattern.

4-5. Suppose a trainee has developed the pattern shown in figure 4, and you are to check it for accuracy. First, check the elevation view for diameter, height, truncation. Next, check the half plan for size and see that the element line points are divided and elevated correctly. Check the elevation view to see that the element lines have been transferred to the outside edge on line AC. If these items are accurate, you have the basis for the pattern for making a correct stretchout arc. Next, check the length of the stretchout arc, the distance between the element lines, and the length of the element lines against the distances between the numbered points on line AC. If all of these items are correct, the pattern should be satisfactory.

4-10. **Seam Allowances.** Seam allowances on a pattern, such as the standing seam allowances on the patterns in figure 6, should be checked for accuracy. In layouts such as this, make sure there is an allowance on one pattern for the pocket of the standing seam and that the allowance for the flange is on the other pattern. Also make sure that the allowance is sufficient for the size of seam being made.

4-11. Another example of additions and allowances is shown in figure 7. These patterns are for the shower stall shown in figure 8. Notice that the shower stall is to be joined with riveted lap seams and Pittsburg lock seams, both of which require allowances. Notice also that the front of the shower stall has a face and flanges that require additions. The patterns in figure 7 include these additions and allowances. When you are checking patterns for additions and seam allowances, make sure the sizes of the patterns are correct and that enough material is allowed. For the patterns shown in figure 7, be sure that the Pittsburg seam pockets are on one pattern and that the flanges are on the other. Next, you should be sure the allowance for the riveted lap seam is sufficient for the metal thickness. The side pieces and the top and bottom front pieces have additions which you should check for correct size.

4-12. **Notching.** Notching is important when fabricating components, since a wrong notch can ruin a pattern; therefore, close supervision of inexperienced workers is necessary. If the patterns in figure 7 didn't have notches, the pieces could not be formed and assembled properly. The bottom and top pieces could not be formed without damaging the corners. If the top and bottom front pieces didn't have notches, the pieces wouldn't fit into the front. Suppose the side pieces were notched all the way to the 32-inch line instead of to the front face line. This would eliminate the ma-

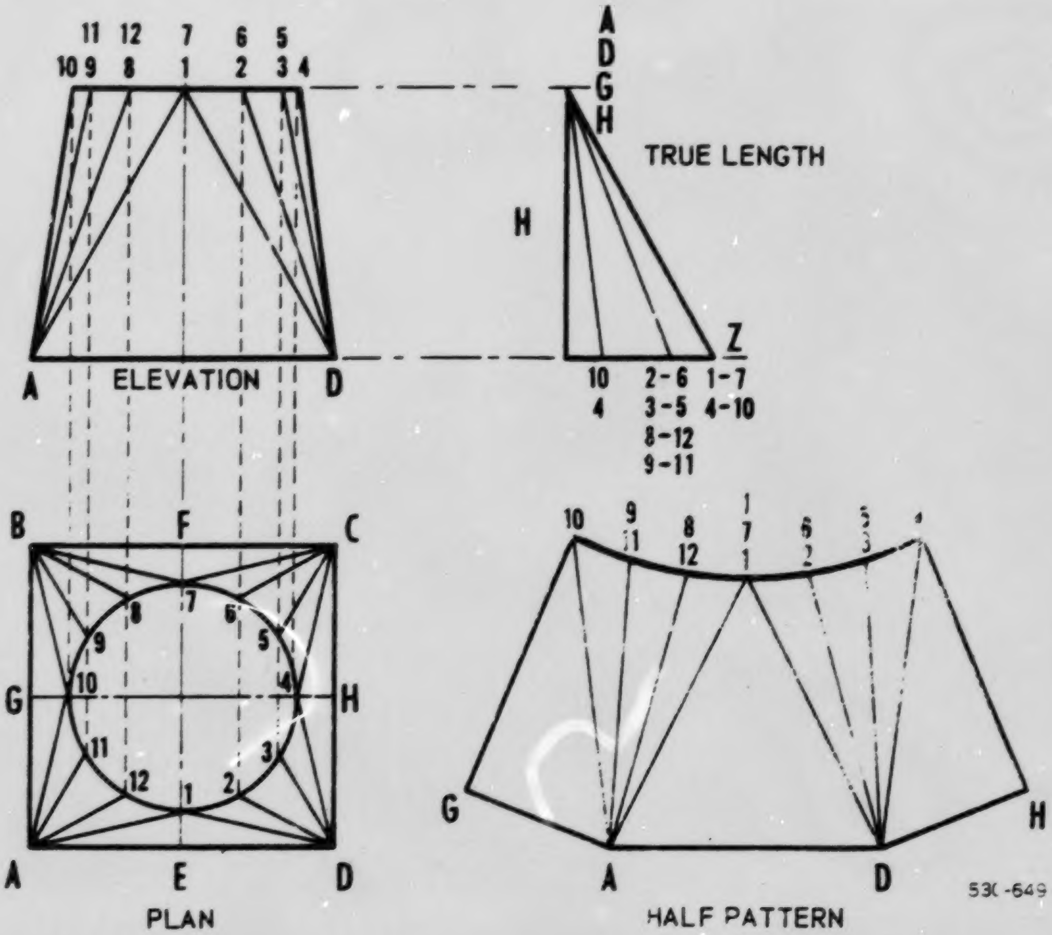
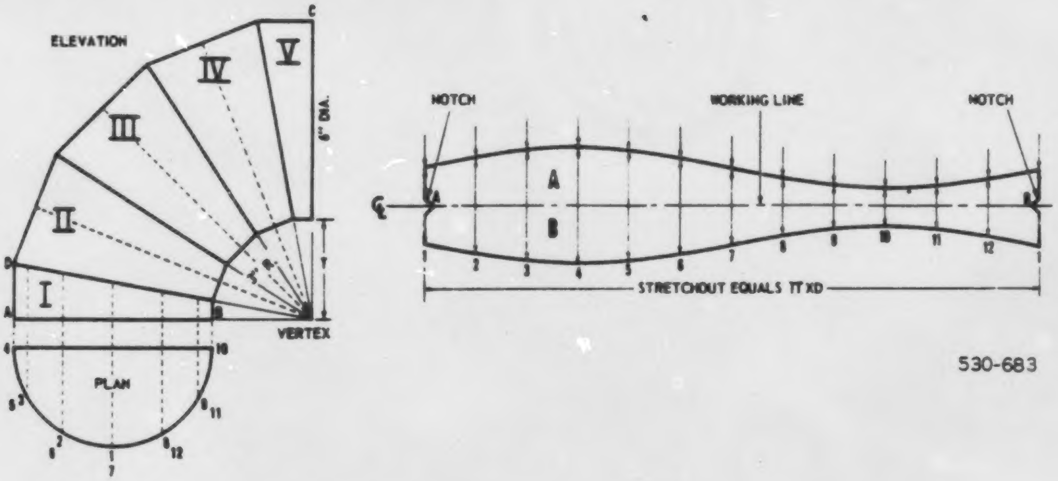
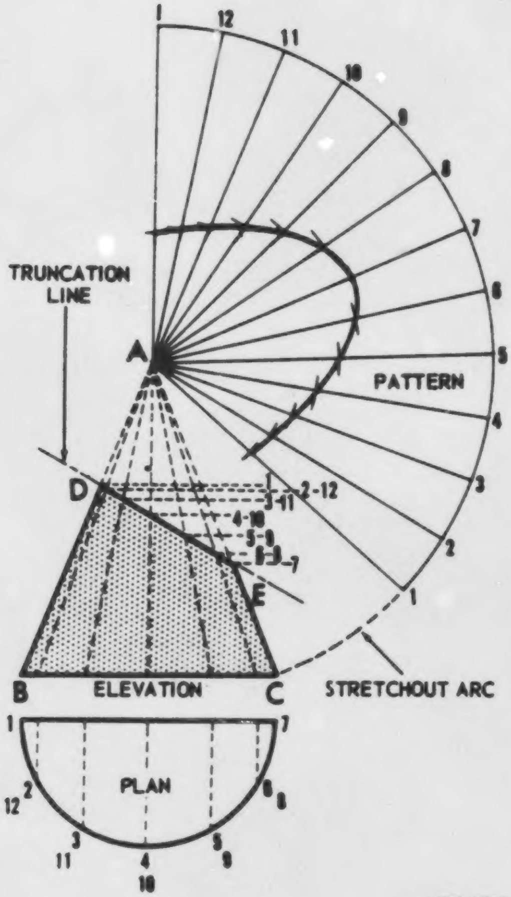


Figure 5. Triangulation development of a transition pattern.


ELEVATION
I
II
III
IV
V
C
6" DIA.
D
A
B
VERTEX
PLAN
NOTCH
WORKING LINE
NOTCH
A
B
℄
1
2
3
4
5
6
7
8
9
10
11
12
STRETCHOUT EQUALS π XD

530-683

Figure 3. Parallel line in development of an elbow pattern.


TRUNCATION LINE
A
PATTERN
D
E
B
ELEVATION
C
STRETCHOUT ARC
PLAN
1
2
3
4
5
6
7
8
9
10
11
12
2-12
3-11
4-10
5-9
6-8
7

530-694

Figure 4. Radial line development of a truncated cone pattern.

4-6. **Triangulation Pattern Development.** Triangulation pattern development is used to lay out transitions, as shown in figure 5. The element lines or sides of the triangles have different lengths, and the true lengths of these lines are needed to develop the pattern. Notice that the illustration includes an elevation view, plan view, and true length chart. In triangulation pattern development, the plan view is made first, so your checking should start there. As in other layout methods, first check the measurements such as base size and top size. Next, check to see that the square base and round top are divided properly. See that the circle is divided into equal parts for the element lines and that lines to the four corners are made correctly.

4-7. Check the elevation view in figure 5 to see that all lines have been transferred correctly and that the height of the transition is correct. After the plan and elevation views are checked, the true length chart should be checked to see that it is a right angle and that the height is correct. Using the length of the element lines from the plan view, make sure the correct length is transferred to the base line of the true length chart.

4-8. Next check the pattern in figure 5 to see that the base line AD is the correct length and that the length of all element lines and the distances between them are correct. If these items are correct, the half pattern should be satisfactory.

4-9. **Additions.** Additions on a pattern should also be checked to see that they are made correctly. Figure 6 shows the patterns for the front, back, and sides of a hood. The bottom of the patterns should have additions for a 6-inch skirt, a 2-inch grease trap, a ½-inch flange, and a $\frac{7}{16}$-inch hem. The top of the patterns should have a 2-inch addition for the collar.

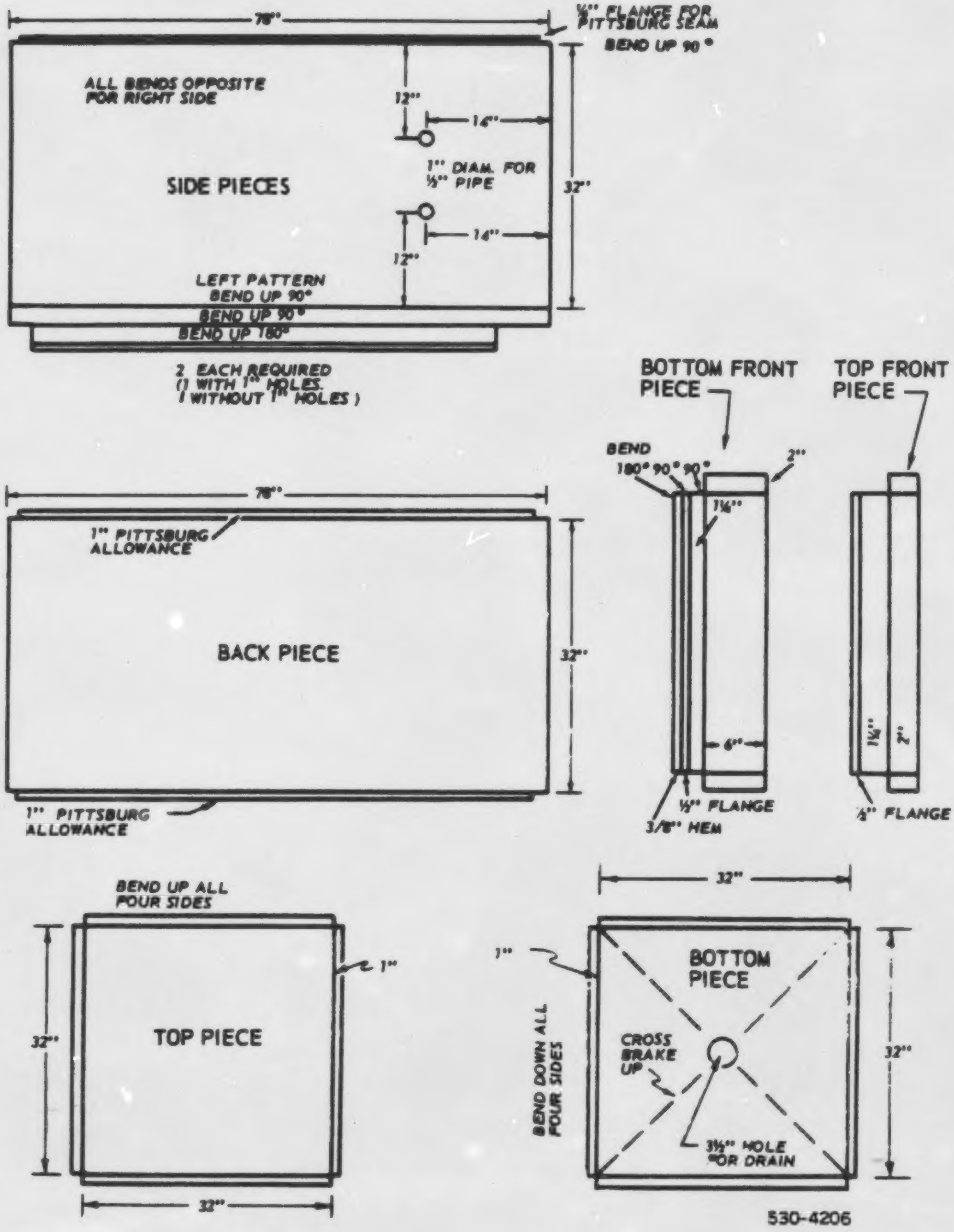

78"
½" FLANGE FOR PITTSBURG SEAM
BEND UP 90°
ALL BENDS OPPOSITE FOR RIGHT SIDE
12"
14"
1" DIAM. FOR ½" PIPE
SIDE PIECES
32"
14"
12"
LEFT PATTERN
BEND UP 90°
BEND UP 90°
BEND UP 180°
2 EACH REQUIRED (1 WITH 1" HOLES. 1 WITHOUT 1" HOLES)
BOTTOM FRONT PIECE
TOP FRONT PIECE
BEND
180° 90° 90°
2"
1½"
78"
1" PITTSBURG ALLOWANCE
BACK PIECE
32"
6"
1½"
2"
1" PITTSBURG ALLOWANCE
½" FLANGE
3/8" HEM
½" FLANGE
BEND UP ALL FOUR SIDES
1"
TOP PIECE
32"
32"
32"
1"
BOTTOM PIECE
BEND DOWN ALL FOUR SIDES
CROSS BRAKE UP
32"
3½" HOLE FOR DRAIN
530-4206

Figure 7. Patterns for a shower stall.

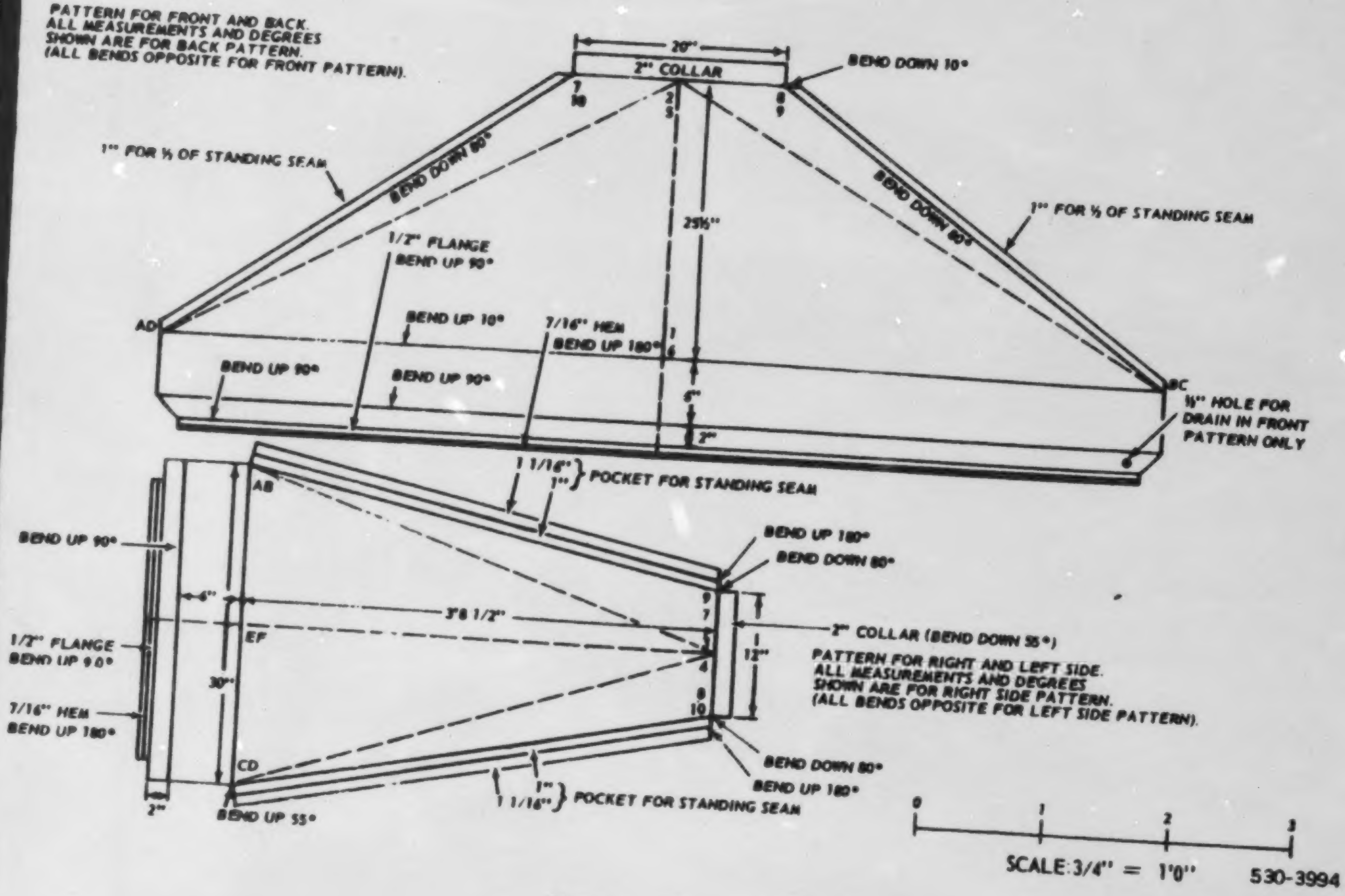

PATTERN FOR FRONT AND BACK.
ALL MEASUREMENTS AND DEGREES
SHOWN ARE FOR BACK PATTERN.
(ALL BENDS OPPOSITE FOR FRONT PATTERN).
20"
2" COLLAR
BEND DOWN 10°
7
10
2
3
8
9
1" FOR ½ OF STANDING SEAM
BEND DOWN 80°
BEND DOWN 80°
1" FOR ½ OF STANDING SEAM
25½"
1/2" FLANGE
BEND UP 90°
AD
BEND UP 10°
7/16" HEM
BEND UP 180°
1
6
BC
BEND UP 90°
BEND UP 90°
6"
2"
½" HOLE FOR
DRAIN IN FRONT
PATTERN ONLY
1 1/16"
1"
POCKET FOR STANDING SEAM
AB
BEND UP 180°
BEND DOWN 80°
BEND UP 90°
6"
3'8 1/2"
9
7
2" COLLAR (BEND DOWN 55°)
1/2" FLANGE
BEND UP 9 0°
EF
1
4
12"
PATTERN FOR RIGHT AND LEFT SIDE.
ALL MEASUREMENTS AND DEGREES
SHOWN ARE FOR RIGHT SIDE PATTERN.
(ALL BENDS OPPOSITE FOR LEFT SIDE PATTERN).
30"
7/16" HEM
BEND UP 180°
8
10
CD
BEND DOWN 80°
BEND UP 180°
2"
BEND UP 55°
1"
1 1/16"
POCKET FOR STANDING SEAM
0
1
2
3
SCALE:3/4" = 1'0"
530-3994

Figure 6. Patterns for a hood.

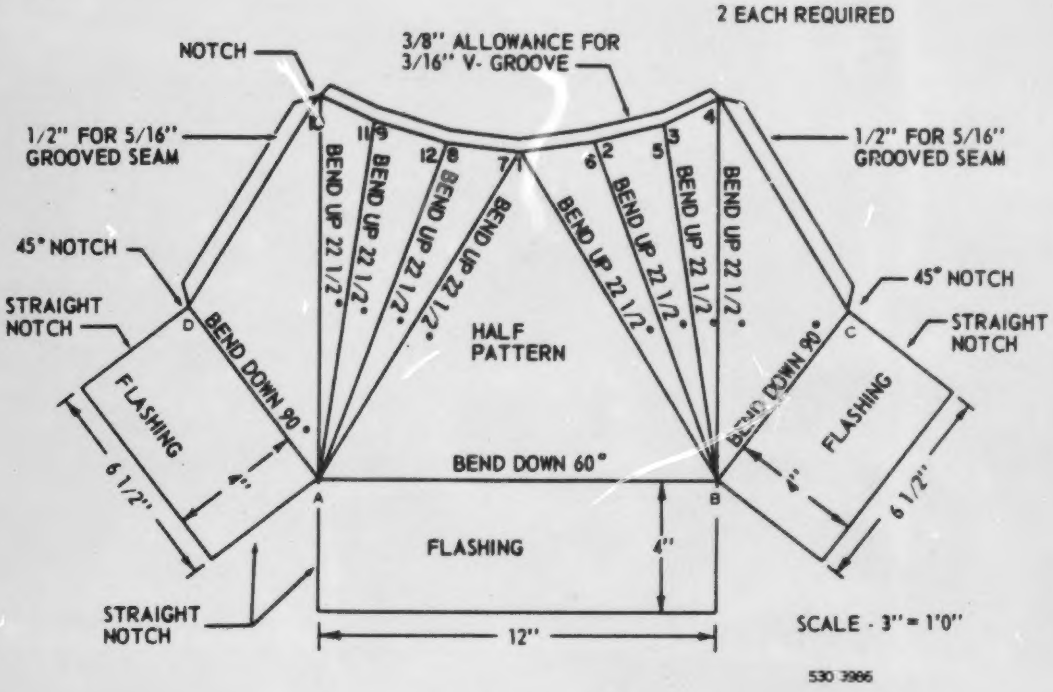

2 EACH REQUIRED
NOTCH
3/8" ALLOWANCE FOR
3/16" V- GROOVE
1/2" FOR 5/16"
GROOVED SEAM
1/2" FOR 5/16"
GROOVED SEAM
45° NOTCH
45° NOTCH
STRAIGHT
NOTCH
STRAIGHT
NOTCH
1
2
3
4
5
6
7
8
9
10
11
12
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
HALF
PATTERN
D
C
A
B
BEND DOWN 90°
BEND DOWN 90°
BEND DOWN 60°
FLASHING
FLASHING
FLASHING
4"
4"
4"
6 1/2"
6 1/2"
12"
STRAIGHT
NOTCH
SCALE - 3" = 1'0"
530 3986

Figure 9. Half pattern for a transition.

terial to fasten the top and bottom front pieces to the side pieces. Mistakes like this are what you should look for when checking patterns for correct notching.

4-13. **Bending Instructions.** Bending instructions are also important in the fabrication of components. A pattern can be developed correctly, including all allowances, additions, and notches; but if the forming is done incorrectly, the component will be defective. For example, if the cross brake lines and the sides are bent down (when bending the bottom pieces in figure 7), the water won't drain to the outlet. This is because cross brake bends would cause the water to flow to the corners instead of the center where the drain is located. If the flange for the Pittsburg seam on the side piece is bent down 90° and the remaining bends are bent up, the face of the shower stall will be turned out instead of in when the pieces are assembled.

4-14. Suppose a trainee is writing the bending instructions on the half pattern shown in figure 9. He has the flashing addition marked to bend up (along lines AB, AD, and BC) and he asks in which direction the element lines are to be bent. Your answer should be "down" because the element lines should bend opposite to the flashing so that the flashing will turn out and the corner will turn in. If the element lines and flashing are bent in the same direction, the flashing will be turned toward the inside of the transition.

4-15. When supervising fabrication of sheet metal components, there are many things to look for. The main thing is to find the mistakes before the patterns are cut out. A good supervisor will keep a constant check on new workers and trainees until they become competent. After the men are qualified and gain the supervisor's confidence, then spot checks are usually sufficient.

5. Checking Sheet Metal Fabrication

5-1. In earlier volumes of this course you learned about tools and equipment used in sheet metalwork and how to fabricate sheet metal components. With this knowledge, you will not find it difficult to supervise other trainees as they learn fabrication operations such as cutting, drilling, punching, folding, forming, and seaming. The following paragraphs will give you many ideas about what to look for and what to emphasize.

5-2. **Cutting Operations.** Checking cutting operations will involve several things, such as the correct cutting of metal and proper use of the machine. You should check to see that the machine or handtool is used with caution, is properly adjusted, and is the right equipment to use; also check to insure that the capacity limitations are not being exceeded.

5-3. *Hand snips and bench shears.* Hand snips and bench shears of all kinds are used to cut metal in the shop and at the job site. When hand snips

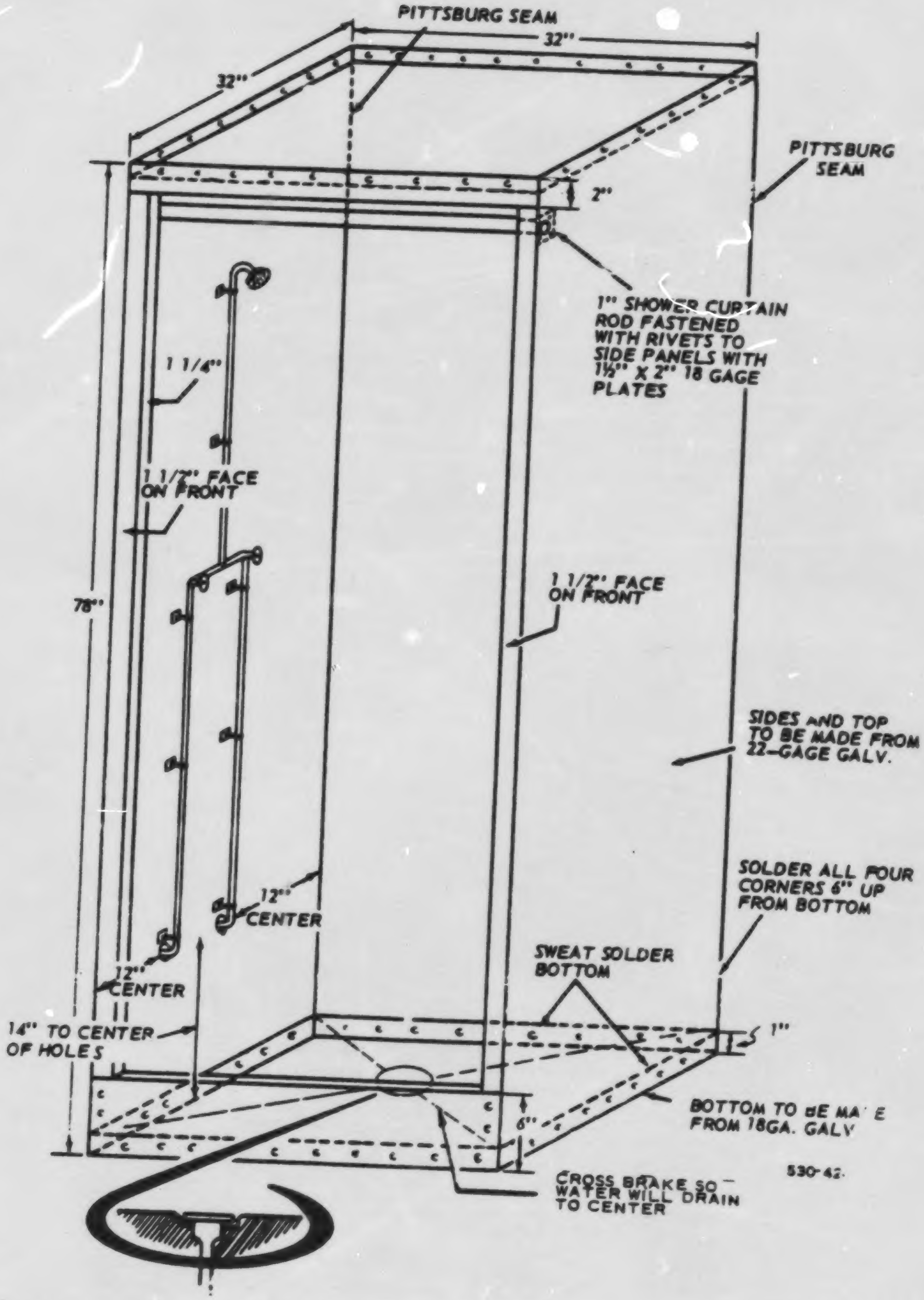

PITTSBURG SEAM
32"
32"
PITTSBURG SEAM
2"
1" SHOWER CURTAIN ROD FASTENED WITH RIVETS TO SIDE PANELS WITH 1½" X 2" 18 GAGE PLATES
1 1/4"
1 1/2" FACE ON FRONT
78"
1 1/2" FACE ON FRONT
SIDES AND TOP TO BE MADE FROM 22-GAGE GALV.
SOLDER ALL FOUR CORNERS 6" UP FROM BOTTOM
12" CENTER
12" CENTER
SWEAT SOLDER BOTTOM
14" TO CENTER OF HOLES
1"
BOTTOM TO BE MADE FROM 18GA. GALV.
6"
CROSS BRAKE SO WATER WILL DRAIN TO CENTER
530-42.

Figure 8. Shower stal .

walk on the material; correct size of twist drill; and correct size or speed of drill. Check the operator for observance of safety precautions.

5-12. *Drill press.* Drill press operation should be checked for correct hole location, center punching, drill size, and drill speed; see that the material is securely clamped to the work table. Be sure that the operator removes the chuck key from the chuck before starting the drill press, and that he does not exert too much force on the feed handle when drilling holes. The operator should be wearing a face shield, safety glasses or safety goggles, and should not have loose clothing that can catch in the rotating drill.

5-13. *Portable electric drills.* Portable electric drills used for drilling operations should be checked for proper grounding of the power cord. (If an extension cord is being used, it should also be checked.) Be sure that the twist drill is securely tightened in the chuck of the drill but not so much that the chuck is damaged. During the drilling operation, be sure that the operator is holding the portable drill straight, firmly, and with enough pressure to make a smooth cut. Too much pressure can damage the drill motor or the twist drill.

5-14. *Lever punches.* Lever punches have a punching capacity that should not be exceeded. The Whitney and hand lever punches are used to pierce holes in light gage metal when the hole is located near the edge of a sheet. Since the two levers come close together when fully depressed, you should check to see that the operator's hands are clear of the levers. Be sure that extension pipes (cheaters) are not used on lever punches. Not only will this ruin the punch and die, but it will also spring the frame of the punch.

5-15. The rotary punch has several dies and punches which have a punching capacity that should not be exceeded. Be sure that the index pin is engaged and that the punch and die are adjusted correctly. As with other lever punches, a cheater should not be used. Also be sure the pattern is center-punched in the correct location, the correct size of punch and die is being used, and the machine is being used properly. The operator should return the lever on the rotary punch to the OPEN position when he is through using the machine.

5-16. *Hand punches.* Hand punches such as center, prick, hollow, and solid punches should be checked for condition of the points, cutting edges, and driving heads. Mushroomed driving heads should be removed by grinding. Be sure that the trainee uses a suitable hand punch and places the point or cutting edge in the correct location on the metal. The trainee should hold the hammer correctly as he strikes the punch. Some people have poor aim with a hammer and can injure their fingers or send the punch flying across the room.

5-17. **Folding and Forming Operations.** Folding and forming operations involve checking the use of machines, seeing that bending instructions are followed, and inspecting the finished component. Folding and forming operations, like other sheet metalworking operations, are very important because an error can cause a defective component.

5-18. *Folding equipment.* Folding equipment such as the bar folder, cornice brake, and box and pan brake is used extensively in sheet metal fabrication. You should make sure that these machines are operated safely and correctly and that the capacity is not exceeded. Suppose a trainee is using the bar folder to make 45° bends and one end of the bend is less than 45°. When he asks what is wrong with the folder, you should be able to give him the correct answer. In this case, one wing pressure screw is not tight enough. If he doesn't know the cause, he probably also doesn't know how to make the adjustment; therefore, you should be able to show him how it is done.

5-19. The cornice brake is used for most folding operations in the sheet metal shop. Check the machine to see that it is adjusted for the gage of metal to be folded, and be sure that the folds are made in the correct location, in the correct direction, and to the desired degree of bend. Remember that one wrong bend can cause a defective component. The cornice brake should also be used as safely as possible, so check the trainee to see that his fingers and hands are kept clear of the bending leaf and bed when the clamping handle is depressed and when the bending leaf is operated. See that the counter-balance weights are secure on the handle and that personnel are clear of the weights when the bending leaf is operated.

5-20. The box and pan brake is used and checked like the cornice brake except for the machine fingers (or shoes). Check to see that the correct number of fingers (or shoes) is installed on the machine properly.

5-21. *Forming equipment.* Forming equipment such as rotary machines, slip rolls, and lock seam forming machines is used in various forming operations. Checks on use, as well as safe operation and proper adjustment, of these machines are similar to checks on other sheet metalworking machines.

5-22. Rotary forming machines such as the beading, elbow edging, wiring, burring, turning, setting down, and crimping machines have various types of roll dies which press the metal into the desired shapes. Your checks should include seeing that the right machine is selected and that the dies are adjusted properly. Caution new operators not to run seams through the machine, because the extra thickness of metal will damage the rolls (dies). When rotary machines are used, they should be securely fastened to a worktable or workbench. You should check the clamp for tightness so that the machine will not fall and be damaged or injure the operator.

(such as straight cut snips, circle snips, and aviation snips) are used to cut metal, you should be sure that the correct kind of snips has been chosen for the jobs. Be sure that the metal is not too thick for the snips and that the snips are in good condition. If the snips are not making a clean cut, check the hinge bolt and the cutting blades. The blades may need sharpening; the wrong snips may have been used; or the bolt may be loose, which would cause the metal to fold at the edges.

5-4. Bench-mounted shears, such as utility shears, throatless shears, and scroll shears, may be used in a variety of cutting operations. You should remember from an earlier volume of this course that utility shears are used for cutout work such as angles and miter joints, and are equipped with an angle gage, miter gage, depth guide, and a cutting blade 6 to 9 inches long. Throatless shears can be used to make continuous cuts, and the metal can be turned in any direction to allow for cutting irregular shapes. Scroll shears are used for cutting circles, ovals, straight or irregular lines, and louver slips without making starter holes. When a trainee is operating bench shears with the hand lever, check to see if there is sufficient clearance to operate the lever handle safely, because the hands and fingers can be injured if caught between the lever and an object. If large pieces are being cut on the throatless shears, it is a good idea to have one man support the sheet while the other man guides the sheet and operates the lever handle. Since most bench shears are mounted so that they can be moved around, you should make sure that they aren't set up where sharp edges of metal will extend into a passageway.

5-5. *Manual and power-operated shears.* Trainees and newly assigned personnel will require close supervision when operating manual and power shears such as squaring shears, gap squaring shears, circle shears, and ring and circle shears. As already mentioned, the lines to be cut should be closely checked on the patterns. Other items you should check include safe operation and correct gage settings. If two men are working together, be sure that each understands what the other is to do.

5-6. When manually operated squaring shears are being used, see that the operator keeps his hands clear of the holddown handles and cutting blades. The back gage at each end of the machine should be correctly set and the metal clamped with the locking handles. The shears are operated by depressing the foot treadle; therefore, you should be sure that the operator keeps his other foot clear of the treadle as it is being depressed. If large sheets are being cut, use two men for the job.

5-7. When cutting operations are being performed on power-operated squaring shears, apply all supervisory measures used for the manually operated shears. Since the treadle on power-operated shears takes very little pressure, there is no danger to the operator's feet. If two men are operating the machine, be sure that only one man operates the treadle. Once the treadle is released, the cutting blade will make a complete cycle; be sure the cutting operation is ready to be performed before operating the treadle.

5-8. When cutting is being done by trainees on circle or ring and circle shears, you should check to see that the machine is set for the correct cutting dimensions. It should make a clean cut all the way through in one revolution of the metal. Check the clamping discs to see that the pressure is sufficient to hold the metal securely during the cut. The horizontal clearance between the cutting blades should also be checked for tightness. The top blade adjustment should be checked to see that it is tight enough to make a clean cut, but not so tight as to damage the cutting edges of the blades. Observe the operator when he is using power-operated circle or ring and circle shears to see that he is standing clear of the metal as it rotates through the machine. Be sure that his clothing can't be caught in the machine or on the edges of the metal.

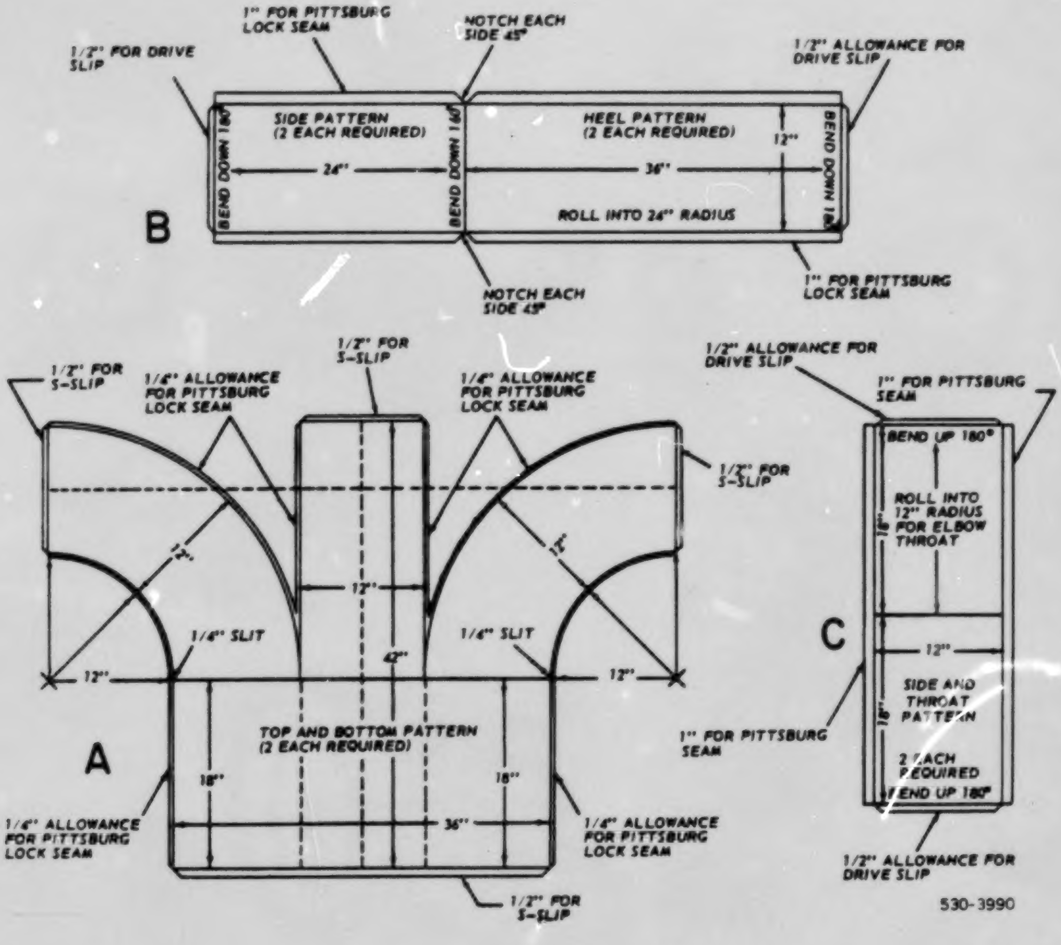
5-9. *Stationary and portable unishears.* Unishears used in cutting operations may be of the stationary or the portable type. You should see that the machines are not overloaded, that enough pressure is applied to obtain a smooth cut, and that safety precautions are followed. Be sure to check the electric power cord for cuts and proper ground connection before use; during cutting operations see that the cord is kept away from the sharp edges of the metal. When using unishears, or any other shears, the operator is usually cutting along a line which should be followed as closely as possible. Make constant checks to see that the operator is performing the cutting operations correctly and spot check the pieces for correct size.

5-10. *Power saws.* Power saws used for cutting metal should have safety guards, and you should make sure that the operator is using them. When using upright bandsaws, the operator should use face and eye protection devices. When power hacksaws are being used, be sure the adjustable vise clamp is tight enough to securely hold the metal during the cutting operation. Check to see that the saw is operated at the speed specified for the type of metal being cut, and that the saw blade is of the correct type and tooth size.

5-11. **Drilling and Punching Operations.** Checking the drilling and punching operations in sheet metalwork is not much different from checking other sheet metal machine operations. The main thing is to know what to look for; if you know how to do the operation yourself, it is not difficult to check the performance of other workmen. When observing drilling operations, check the location of the hole; center punching, so that the drill won't equipment, size and location of rivet holes, and appearance of the assembled seam.

5-28. *Grooved seams.* Grooved seams can be made several ways and in many sizes, as you should recall from an earlier volume of this course. You learned that grooved seams require a material allowance of three times the seam width plus three times the metal thickness for light gage metal or five times the thickness for heavy gage. If a grooved seam is being made by hand, the bends should be correct, and the proper hand groover should be used to set the seam. For example, if the seam is ¼ inch wide, a ${}^5/_{16}$-inch hand groover should be used to set the seam. After assembly, check the seam to see that it is fastened the full length and that it does not slip. If a grooved seam is being made on the Pittsburg lock forming machine, check for correct seam allowances and see that the metal is run through the machine properly. The machine will turn the metal so that the pocket is up as it comes out of the rollers. Make certain that each pocket is formed on the correct side of the metal. After the two pockets are formed and the seam is assembled and set with a mallet, see that the seam is center-punched to make certain it will not slip.

5-29. *Pittsburg seams.* Pittsburg seams consist of two parts—the flange and the pocket—and are used at square corners to join the edges of metal. This seam, like other seams, requires a material allowance. You should check for the correct allowance for the pocket and flange. The location of the pocket and flange should be checked because an inexperienced worker or trainee may form the pocket (or flange) on the wrong piece. For example, in figure 10, the Pittsburg seam pocket is made on the bottom piece (pattern B) and the flange on the sides (pattern A). If the allowance for the pocket is erroneously made on the sides, it would be impossible to run the side pieces through the Pittsburg lock forming machine without bending other parts. The allowance for Pittsburg seam



1" FOR PITTSBURG LOCK SEAM
NOTCH EACH SIDE 45°
1/2" FOR DRIVE SLIP
1/2" ALLOWANCE FOR DRIVE SLIP
SIDE PATTERN (2 EACH REQUIRED)
HEEL PATTERN (2 EACH REQUIRED)
BEND DOWN 180°
24"
36"
12"
ROLL INTO 24" RADIUS
B
NOTCH EACH SIDE 45°
1" FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
12"
12"
12"
1/4" SLIT
42"
1/4" SLIT
12"
12"
TOP AND BOTTOM PATTERN (2 EACH REQUIRED)
A
18"
18"
36"
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/4" ALLOWANCE FOR PITTSBURG LOCK SEAM
1/2" FOR S-SLIP
1/2" ALLOWANCE FOR DRIVE SLIP
1" FOR PITTSBURG SEAM
BEND UP 180°
ROLL INTO 12" RADIUS FOR ELBOW THROAT
C
12"
SIDE AND THROAT PATTERN
2 EACH REQUIRED
BEND UP 180°
1" FOR PITTSBURG SEAM
1/2" ALLOWANCE FOR DRIVE SLIP
530-3990

Figure 11. Patterns for a takeoff joint.

5-23. Suppose a trainee is using a crimping machine to form a crimp and bead on a round duct slip joint. You should check to insure that the gage on the machine is set for the distance specified to make the slip joint, and that the top roll is adjusted so that all of the crimp will not be made in one revolution. The first revolution should be just enough to make an impression in the metal. Repeated tightening and revolutions will produce the desired depth of crimp. Excessive tightening and attempting to make the entire crimp and bead on the first revolution make the operating handle hard to move and put undue strain on the rollers and shafts.

5-24. When the rotary burring machine is used to turn 90° flanges, check to insure that the operator is not tightening the upper roll so that it cuts into the metal. Inexperienced workers often do this when trying to turn an edge in one revolution. You should make checks to see if the turned edge is weak, because if the upper roll is too tight the metal can be weakened although not cut through.

5-25. Slip roll forming machines (manual and power) are used to form such items as round ducts or radius bends for the heel and throats of square and rectangular duct. As with other sheet metal-working machines, the successful operation of the slip roll is affected by proper adjustment—the lower front roll for gripping pressure and the lower rear roll for the desired radius of bend. The machine should not be overloaded, since it can be damaged by such misuse. Caution the operators not to bend wire or rod except in the grooves provided for that purpose. The power slip roll is very dangerous for inexperienced operators: therefore, you should closely supervise new operators. If a job requires large sheets to be formed and two men are performing the operation, each man should know his tasks as well as the other man's. You should see that loose clothing is not worn by anyone operating the power slip roll.

5-26. The Pittsburg lock forming machine is used to make Pittsburg and grooved seams. Check to see that the machine is adjusted correctly for the thickness of the metal and that it is not overloaded. Folds made on the Pittsburg machine should be checked carefully to determine that the metal has not been weakened by too tight an adjustment, that the seam is made on the piece for which it was intended, that there is enough locking flange on the pocket side of the Pittsburg lock seam to hold the seam tight, and that the pocket is formed on the correct side of the metal. When grooved seams are made for round ducts, the metal should be checked to be sure that one pocket is up and the other pocket is down, so that the seam can be joined.

5-27. **Seaming Operations.** When checking seaming operations, include such items as seam allowance, location on the pattern, use of seaming

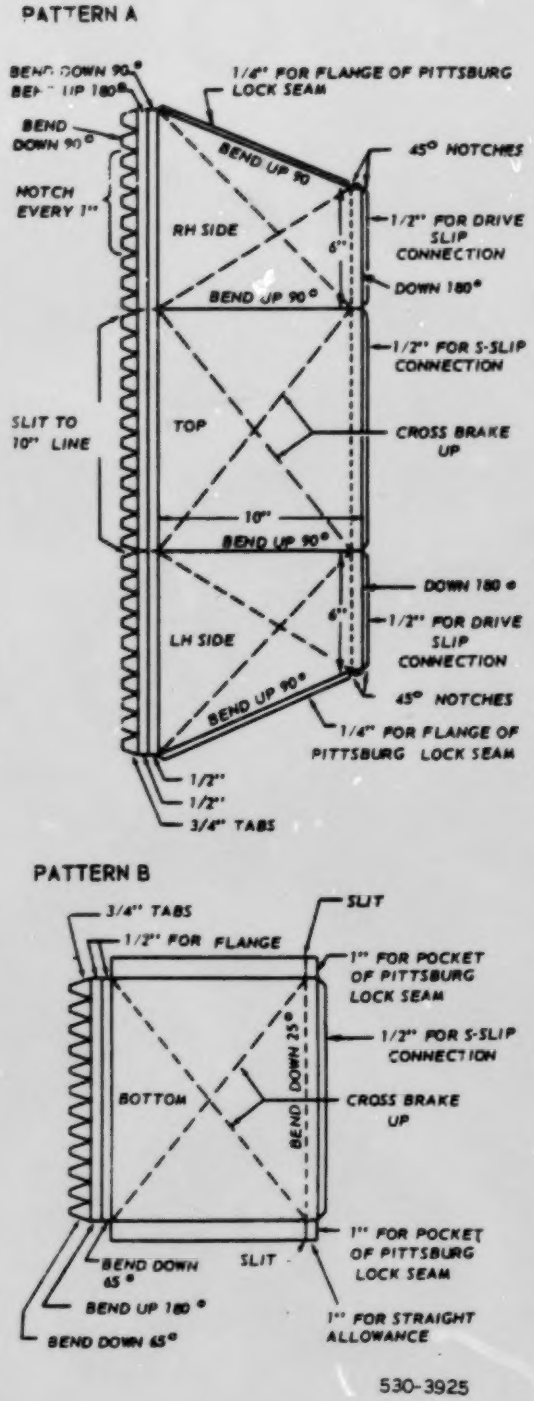

PATTERN A
BEND DOWN 90°
BEND UP 180°
1/4" FOR FLANGE OF PITTSBURG LOCK SEAM
BEND DOWN 90°
NOTCH EVERY 1"
BEND UP 90
45° NOTCHES
RH SIDE
6"
1/2" FOR DRIVE SLIP CONNECTION
BEND UP 90°
DOWN 180°
1/2" FOR S-SLIP CONNECTION
SLIT TO 10" LINE
TOP
CROSS BRAKE UP
10"
BEND UP 90°
DOWN 180°
6"
LH SIDE
1/2" FOR DRIVE SLIP CONNECTION
BEND UP 90°
45° NOTCHES
1/4" FOR FLANGE OF PITTSBURG LOCK SEAM
1/2"
1/2"
3/4" TABS
PATTERN B
3/4" TABS
SLIT
1/2" FOR FLANGE
1" FOR POCKET OF PITTSBURG LOCK SEAM
1/2" FOR S-SLIP CONNECTION
BEND DOWN 25°
BOTTOM
CROSS BRAKE UP
BEND DOWN 65°
SLIT
1" FOR POCKET OF PITTSBURG LOCK SEAM
BEND UP 180°
BEND DOWN 65°
1" FOR STRAIGHT ALLOWANCE
530-3925

Figure 10. Patterns for a takeoff fitting with tapped connection.

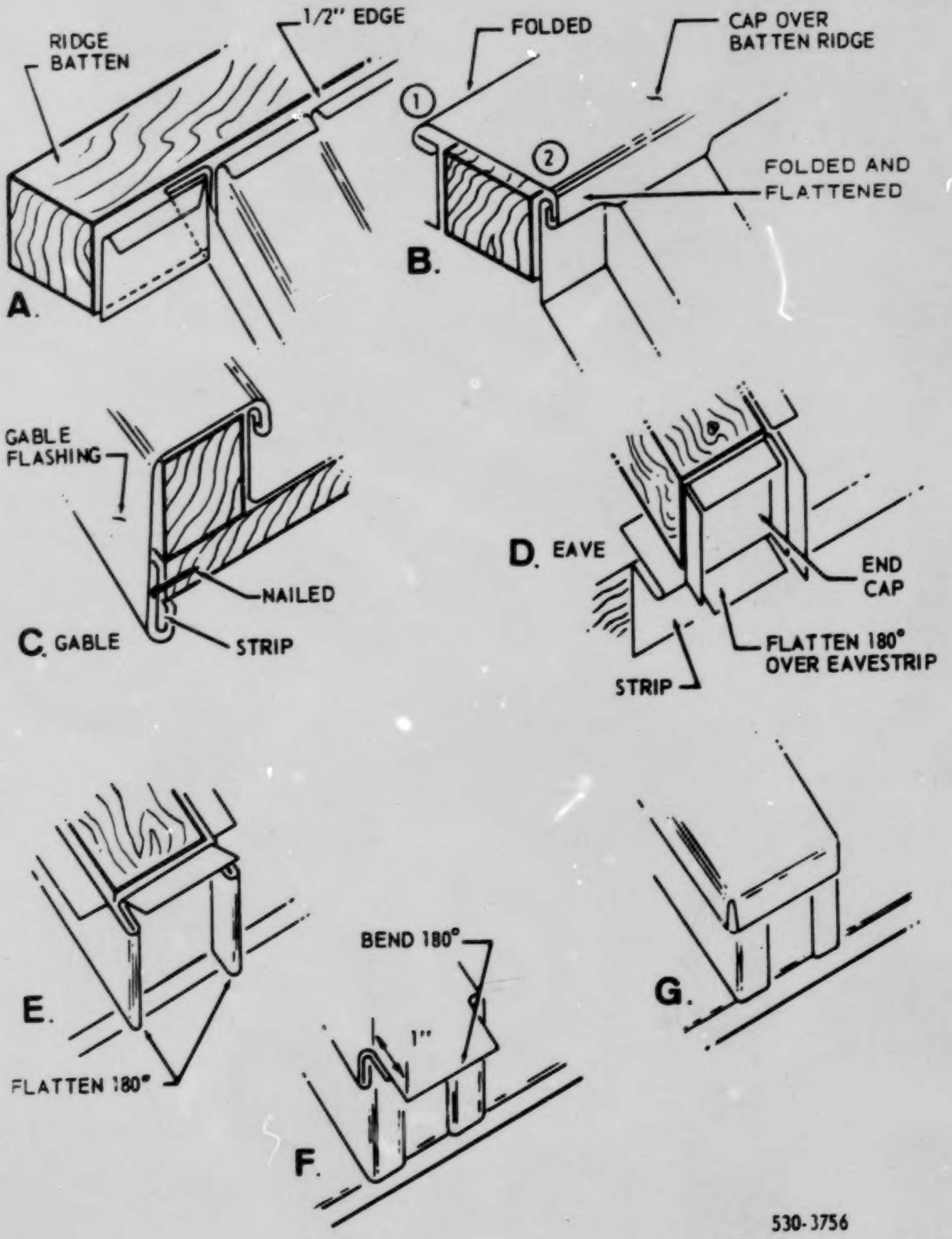

RIDGE BATTEN
1/2" EDGE
A.
FOLDED
CAP OVER BATTEN RIDGE
①
②
FOLDED AND FLATTENED
B.
GABLE FLASHING
NAILED
C. GABLE
STRIP
D. EAVE
END CAP
FLATTEN 180° OVER EAVESTRIP
STRIP
E.
FLATTEN 180°
BEND 180°
1"
F.
G.
530-3756

Figure 13. Batten seams used with metal roofing.

pockets should be made on the pieces that have straight sides so that the piece can be run through the machine. With the allowance for the pocket correctly made on the bottom piece, the slits can be made and the piece formed. Another example is the use of a Pittsburg lock seam to assemble a rectangular elbow. In figure 11 notice that the allowance for the pocket of the Pittsburg lock seam is on the throat and heel patterns, and the ¼-inch allowance for the flange is on the top and bottom patterns. The round edges on the top and bottom patterns cannot be run through the Pittsburg machine; therefore, the pockets should be formed on the straight edges of the heel and throat pieces. These pieces can be formed to the desired radius in the slip roll forming machine after the pocket is formed with the Pittsburg machine.

5-30. The pocket of a Pittsburg lock seam should be deep enough so that the flange can be inserted with enough material available to bend over to lock the flange in the pocket. When the flange is turned 90°, it should be free of wrinkles so that it will slip easily into the pocket during assembly. Since the flange is slipped into the pocket, you can check to see that it is correctly seated by looking inside the component. If it is not well seated, you can see a hump or space between the pieces. The flange is held in place by the locking edge of the pocket bent over the flange. The metal should be smooth and free of wrinkles.

5-31. *Dovetail seams.* Dovetail seams are used to connect cylindrically shaped components to flat bases. The dovetail seam has tabs that fasten the component to the flat surface. You should remember that before installation, every other tab is bent 90°; after installation, the remaining tabs are bent 90° on the opposite side of the flat base. Dovetail seams are easy to make and should not require close supervision. You should check to insure that the tabs have been cut and formed correctly and, where specified, soldered correctly.

5-32. *Standing seams.* The checking of standing seams will vary according to how they are being used. For example, earlier in this course you learned that 1½-inch standing seams should be used on 4-foot centers to stiffen 24-gage duct joints that are 31 to 40 inches wide and 7 feet 11 inches long. Cross brake stiffening is necessary, and standing S-slips and drive slips should be used at the joint connections. When checking a fabrication like this example, you should see that the stiffening meets the specifications for bracing and for type of joint connectors, that the layout and seam allowances are correct, and that the fabrication and installation are correct. In this example you were given the size of the seam; but if the metal thickness is different, it may be necessary to determine a different size of seam.

5-33. If you are supervising the installation of a roof where standing seams are used, the things to look for are a little different. You should check to

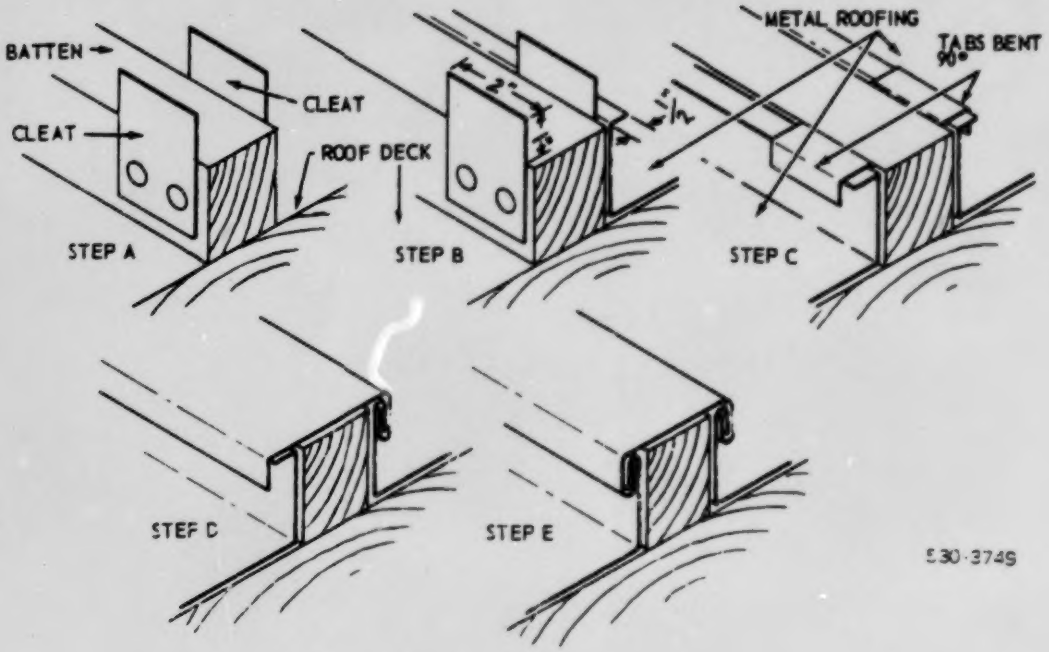


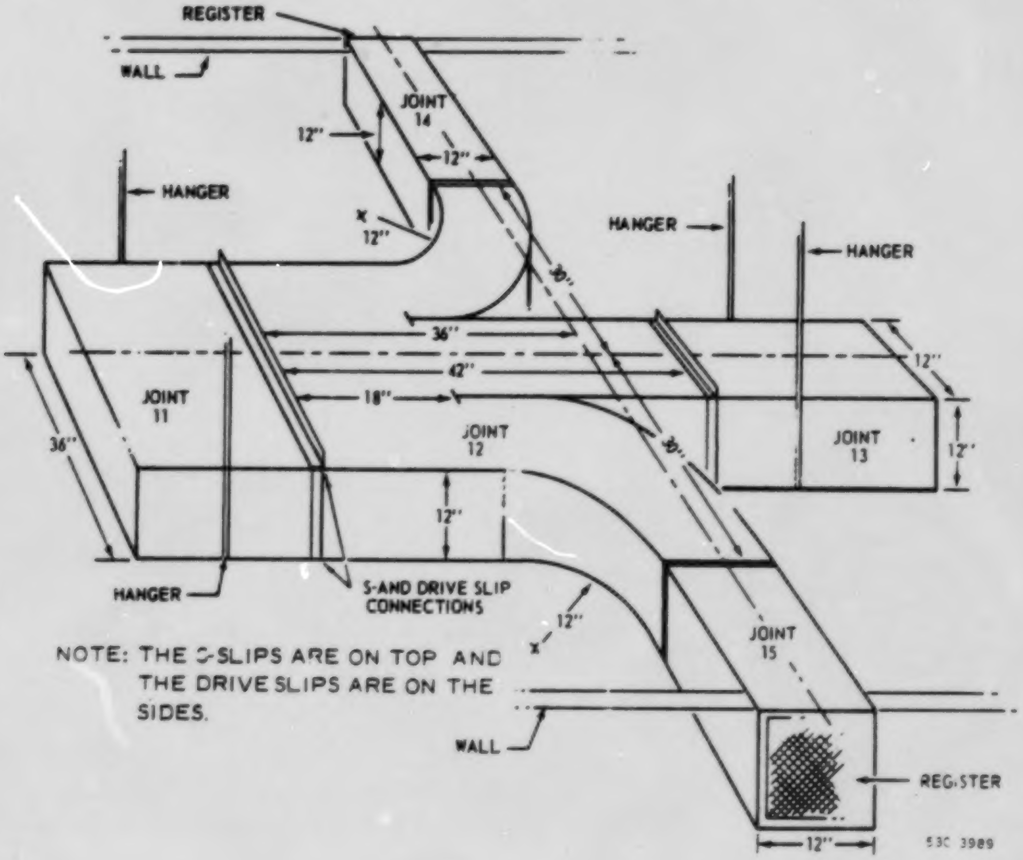
Figure 12. Making a batten seam

see that the cleats are spaced according to specifications, that the seam size is in accordance with specifications, that correct allowance for expansion is made, and that the seam is made correctly.

5-34. *Lap seams.* Lap seams were also discussed earlier in this course, and you should know the various ways they can be used. However, each different way will require some variation in the supervisory checks. When a plain or offset lap seam is used on flat sheets, the seam should be checked for material allowance, rivet size, hole size, rivet spacing, and distance from the edges of the lap to the center of the rivet holes. If the lap seam is an inside or outside corner lap, the same checks are made except that the seam allowance is made only on one side of the lap.

5-35. When lap seams are used on roofing, the sidelaps are determined by the number of corrugations, ribs, or V-crimps specified on the drawing or work order. The sidelaps are made so that the sheets will lap in the direction of the prevailing wind. Therefore, as a supervisor or crew leader on the job, you should observe and see that the job is being installed according to specifications. For example, if you are installing a corrugated roof using 1½ sidelaps, you should make certain that the top sheet laps the bottom sheet one crown and one valley. You should also see that the correct fasteners are being used, that dissimilar metals *are not* being used, that the fasteners have a sealing washer, and that the fasteners are being installed correctly. The endlaps should be checked to see that the metal laps according to specifications and that the top sheet laps over the bottom sheet in the direction of water flow.

5-36. *Batten seams.* Batten seams are used when installing metal roofs and must be fabricated correctly to prevent leaks at the seams. Since batten seams are fastened to the roof deck with cleats, you should check the spacing, check to see that the cleats are fastened to the deck, and see that there is enough material to form into the seams. In figure 12, step B, you can see that ½-inch seams are used on the batten. The cleat is 2 inches wide and extends above the batten 1 inch. The 1-inch allowance will be formed into the seam. The completed seams shown in steps D and E are well formed and are examples of what you should see when check-



NOTE: THE S-SLIPS ARE ON TOP AND THE DRIVE SLIPS ARE ON THE SIDES.

Figure 15. Duct system takeoff (joint 12).

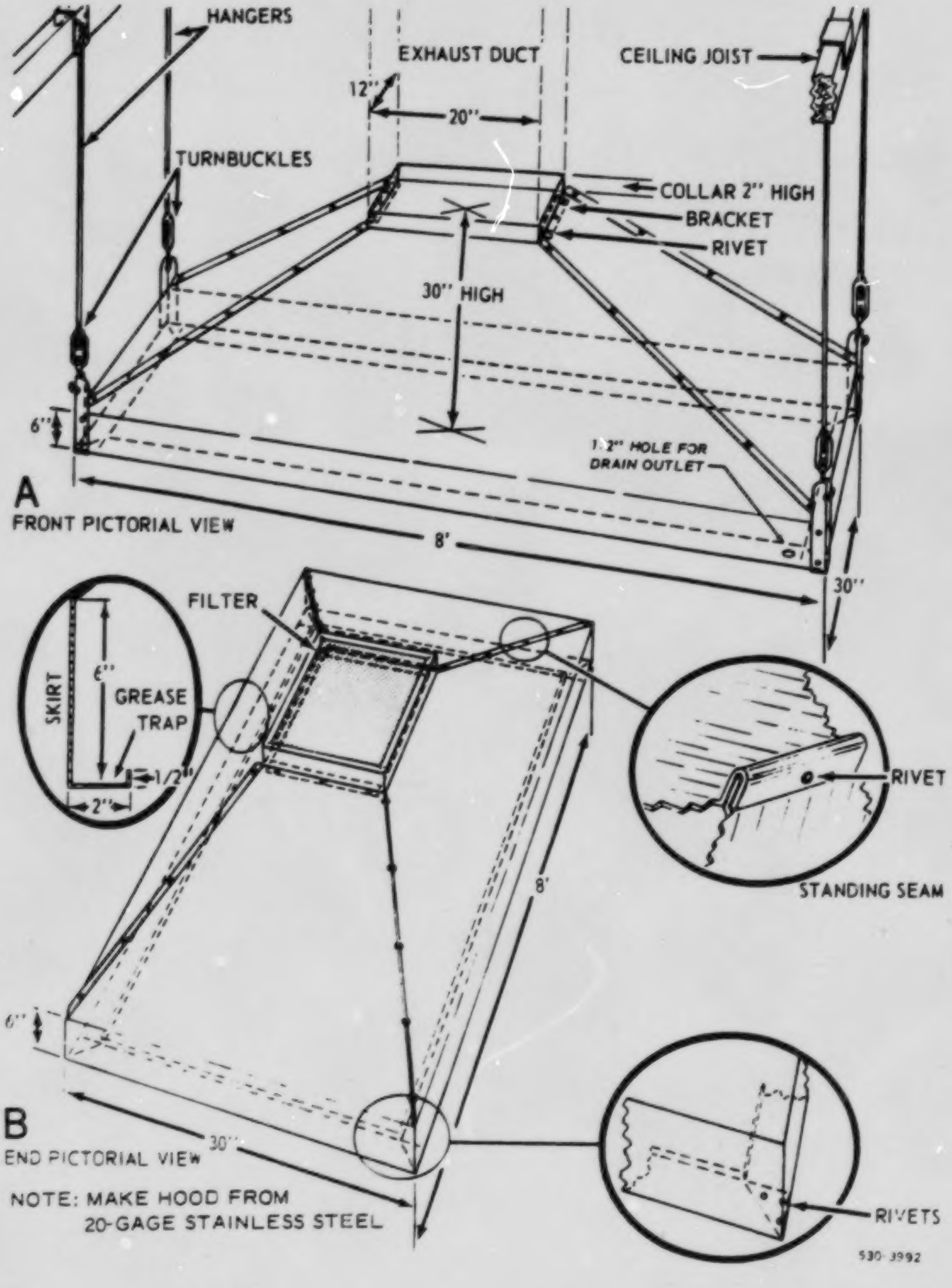

HANGERS
EXHAUST DUCT
CEILING JOIST
12"
20"
TURNBUCKLES
COLLAR 2" HIGH
BRACKET
RIVET
30" HIGH
6"
1/2" HOLE FOR DRAIN OUTLET
A
FRONT PICTORIAL VIEW
8'
30"
FILTER
SKIRT
6"
GREASE TRAP
1/2"
2"
RIVET
STANDING SEAM
8'
6"
B
END PICTORIAL VIEW
30"
NOTE: MAKE HOOD FROM
20-GAGE STAINLESS STEEL
RIVETS
530-3992

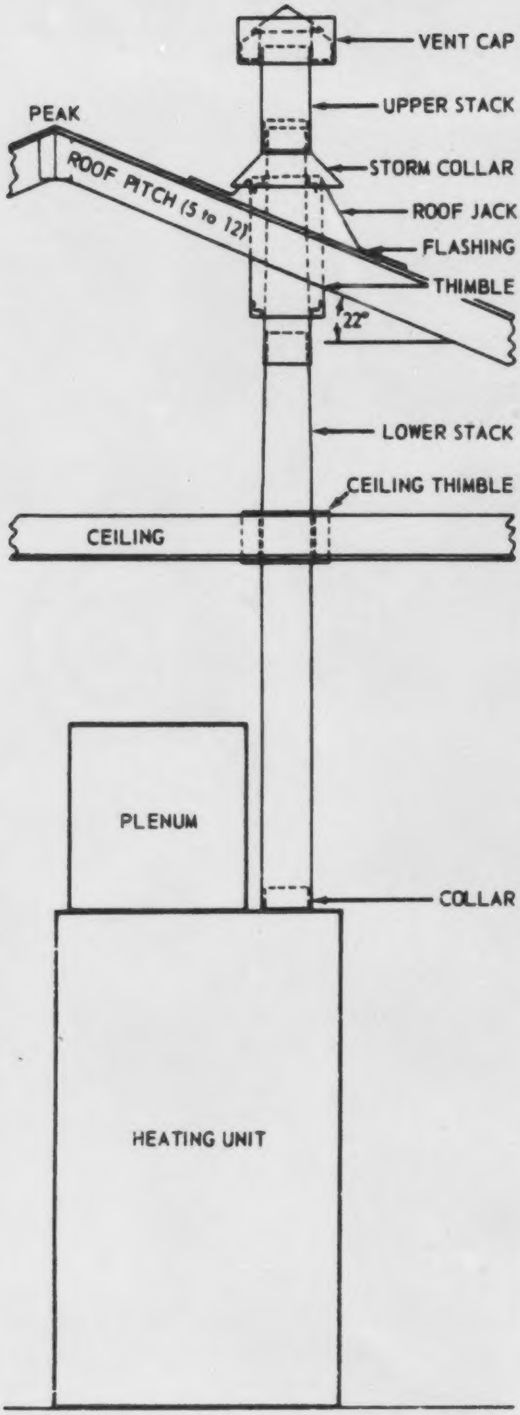
Figure 14. Pictorial views of a hood.

that are adjustable for leveling the hood during installation.

6-3. After installation in a building, the hood should be inspected to see that the hangers are securely fastened to the ceiling joists and that they are plumb. The height of the hood should be checked to see that it meets specifications on the drawing or work order. In this example, the hood is 6′ 6″ from the floor (a distance which is often used for hood installations). An inspection should be made to see that the corner with the drain plug is slightly lower than the other corners so that grease and water can be drained from the grease trap. The exhaust duct and connection should be inspected for a good fit at the collar and at the joint connections.

6-4. **Duct Repair and Installation.** Joint 12 in figure 15 is a completed and installed takeoff joint. Before a joint such as this is installed, you should inspect it for correct dimensions, material thickness, and construction. After installation, you should see that it fits properly at all joint connections, that the hangers have been refastened, that the registers have been replaced, and that the overall workmanship is satisfactory. When checking for workmanship, you should see that the flanges on the Pittsburg seams are flattened properly, that all drive slips have been turned down properly and that any rough corners have been rounded off.

6-5. **Stack Repair and Installation.** A completed and installed stack assembly is shown in figure 16. Assume that you have already supervised the fabrication and are ready to inspect it for proper installation. First, you should see that the stack is plumb and straight and that all joint connections are made correctly. You should check the flashing of the roof jack for good sealing. Check the storm collar to see if it is installed over the roof jack opening so that air can pass but rain will be kept out. Check the height of the vent cap and upper stack and see if guy wires will be needed. Since a stack must safely carry heat fumes from a building without any leakage or overheating, you should check the stack and its components for any deficiency that could become a safety hazard.



530-3987

Figure 15. Single wall stack and associated components.

ing batten seams. In figure 13 you can see how batten seams are finished at the ridge, gable, and eave of a roof. Notice how the seams are formed to seal the roof from leaks. In checking seaming operations, you should be sure that the seams are locked and folded correctly, because any open seams would allow water seepage and damage to the roof.

6. Checking Fabricated and Repaired Items for Accuracy and Quality

6-1. Inspection of fabricated and repaired items is a very important part of sheet metal supervision. When a job is inspected and approved, the supervisor's reputation is "on the line." If the job is faulty, he will be the first to hear of it and will be responsible for its correction. On the other hand, if the job is exceptionally good, he should also be the first to hear about it. In turn, he should let the workers know how their work is rated. You will find that most workers take pride in their work and that compliments, when deserved, will encourage them to improve their work even more. This pride will "rub off" on trainees and other workers and will help make the job of supervision easier. Therefore, when inspecting jobs, you should not only point out mistakes but you should point out the good qualities, too. In the preceding sections of this chapter we have discussed the checks to be made during layout, fabrication, and assembly of sheet metal components. In this section we are primarily concerned with inspection checks related to completed or installed sheet metal components. However, you will find that close observation during layout, fabrication, and assembly will make the final inspections much easier and will usually eliminate most of the problems that might be encountered on final inspection. In the following paragraphs we will discuss the inspection checks for hood fabrication and installation, duct repair and installation, and stack repair and installation.

6-2. **Hood Fabrication and Installation.** The hood shown in figure 14 has been fabricated and is to be inspected by you before being installed in a building. The hood should be made from 20-gage stainless steel as indicated on the drawing. The dimensions should be the same as specified on the drawing. The seams should be correctly made and assembled and the rivets correctly installed. The corner laps should be soldered and leakproof. The surface of the stainless steel should not have scratches or bends that will mar the appearance of the hood. The workmanship should be inspected to see that burrs have been removed, that corners are flush and square, and that the overall appearance of the hood is good. The filter should be easy to remove for cleaning. The hangers should be inspected for specified materials, good welds, bends that do not weaken the material, and turnbuckles

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in the linkage, blades, or frame. The gear or linkage that controls the blades may become worn or bent and cause hard or improper operation of the blades. The blades of multiple-blade registers, such as the one shown in figure 17, can also become bent so that they operate incorrectly. Bending of the frame on most types of registers causes hard operation, or prevents operation, of the blades.

7-7. Diffusers that are bent or damaged will be difficult to operate. Most diffusers have a shaft with a worm gear (or chain) which adjusts the size of the opening and regulates the airflow. The worm gear (or chain adjustment) is easy to get to and should be checked first if the diffuser blades do not adjust properly.

7-8. *Stacks and ventilators.* High winds can cause damage to stacks and ventilators by blowing the stack over or blowing the vent cap off. When a stack assembly, such as that shown in figure 16, blows over, check the flashing, storm collar, upper stack, roof jack, and vent cap for loose fasteners, fasteners that have pulled through the metal, bends in the metal, and seams that may have been damaged. Check the roof jack and flashing for damage to the soldered seams. Check the flashing for looseness on the roof deck and the sealant around the flashing for damage. Check the guy wires that may have broken or pulled out of the stack or roof deck. Check the fasteners where they have been installed in the roof deck as well as where they attach to the stack.

7-9. Ventilators which have been damaged by the wind will need to be checked in a manner similar to that for stacks. If a ventilator is damaged, inspect it for holes, cracks, or bends in the metal. Check the braces and fasteners as well as the seams to see if any are defective. Check the soldered seams and joint connections for leaks.

7-10. Damaged turbine ventilators may have bends in the vanes of the turbine or may have a bent shaft. You can detect a bent shaft if the turbine wobbles as it turns. There will be times when the bronze or roller bearings on the turbine shaft become defective. This condition can be detected by moving the turbine from side to side and observing for excessive play in the movement. To determine which bearing has the wear, it may be

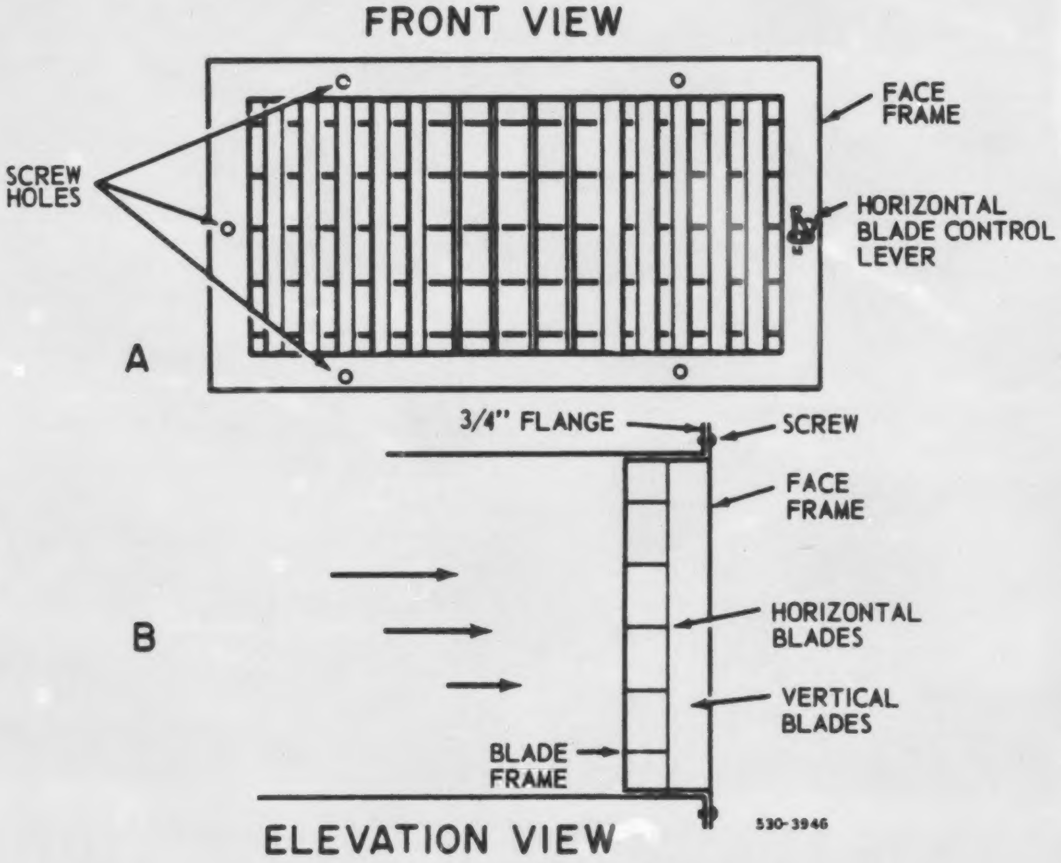


Figure 17. Multiple-blade register.

Determining Job Requirements

IN THIS CHAPTER we will discuss how to determine job requirements in the repair or replacement of sheet metal components. The word "determine" means to reach a decision after thought and investigation. You have probably heard the term "total damage" when an insurance adjuster checks a damaged automobile. Have you ever stopped to think why or how he determined that the damage was total? In making the decision, he took into consideration the cost of time and material and weighed it against the cost of replacing the vehicle. He also took into consideration how well the automobile would operate if repaired. This is similar to what you will be doing when determining job requirements for sheet metal repair. You will inspect the damage (or deterioration), evaluate the damage, and determine the limitations and the method of repair.

2. You need to study this chapter so that you can make the right decisions when determining job requirements. What do you suppose would happen if the insurance adjuster made a wrong decision? The cost of repair could be more than the car is worth; on the other hand, a car might be replaced when repair could have been made at less expense. To prevent errors in sheet metal repair, you should learn how to make the right decisions so that the cost of repairs can be held to a minimum.

3. You can use the information from this chapter to help you make sound decisions after inspecting components for damage or deterioration. As a 5-level sheet metalworker, you can use this information to supervise or lead other workers in doing good repair.

7. Inspecting Sheet Metal Parts for Damage or Deterioration

7-1. In this section we will discuss how to inspect for damage and deterioration of such sheet metal components as ducts, stacks, ventilators, roofing, gutters, awnings, and shower stalls.

7-2. **Inspecting for Damage.** When a sheet metal component is damaged, you can usually spot it right away. By "damage" we mean such things as bends or breaks in the metal, broken rivets or screws, or metal that has pulled away from the screws or rivets. In addition, there are other things to be visually inspected such as areas where braces, joint connections, or seams may have been weakened. You should also examine the component, roofing, siding, or equipment to determine if the damage was caused by faulty construction. It is necessary in some instances, when making repairs, to improve the condition of the component with bracing, additional hangers, rivets, or screws that may be needed.

7-3. Wind damage usually results in metal being pulled away from fasteners or the fasteners working loose; in either case, the force of the wind can bend the material. If the metal pulls away from the fasteners or the fasteners work loose, there is a good indication that additional fasteners are needed.

7-4. Fire damage should be thoroughly inspected, because the heat has probably caused the metal to weaken and stretch out of shape. The heat may have been so intense that it damaged the zinc coating on the galvanized sheets. With the protective coating gone, the surface is susceptible to corrosion, and all of the damaged metal should be replaced. When a grease fire occurs in an exhaust hood, the stainless steel will lose its luster and should be repaired if the hood is to be restored to its original appearance. When any type of fire has occurred, all soldered seams and joint connections should be inspected to see if they are still liquid tight.

7-5. *Registers, diffusers, and louvers.* Damage to registers, diffusers, and louvers usually involves broken or bent blades, frames, linkage, or operating handles. In addition to visible damage, you can expect to find hidden damage when the blades or control handles are difficult to operate. For example, suppose an automatic louver will not open and you are to inspect it for possible damage. Since automatic louvers are operated by a motor, spring, or air pressure, the linkage or blades may be broken or bent.

7-6. Registers that do not operate correctly should be inspected for damage, which is usually most likely causes of damage to metal roofing; however, snow, ice, or hail may also cause damage.

7-12. When corrugated metal roofing (such as that shown in fig. 18) has been damaged by wind, make a thorough inspection before beginning any work. The fasteners on lap seams may have worked loose or the metal may have been torn away from the fasteners. As you inspect, look for loose sidelaps and endlaps and for edges that are bent. Also check the sheets surrounding the damaged area for possible failure of fasteners. Winds that are strong enough to cause damage to one section of roofing are also strong enough to cause damage to other sections of the roof. Check standing and batten seam roofing to see if the seams have been damaged. Since cross seams are soldered, check for breaks in the solder.

7-13. If a metal roof has been damaged by a falling object, your inspection will depend on the size and impact of the object. If the object was not too large, the hole may be patched or the sheet replaced. If the object has hit a seam, it may be necessary to replace two or more sheets. If the object has hit a corrugated roof, the deck below the corrugated sheet is probably open and may not be damaged. If the roof deck purlins or any structural bracing has been damaged, consult the engineering section of your civil engineering group for additional assistance.

7-14. If snow or ice builds up on a metal roof, check for damage such as bent metal or broken fasteners. This type of damage is more likely to be found on prefabricated buildings that are unheated. The damage is usually close to the eaves of the building where ice forms from the melting snow.

7-15. *Flashing.* Inspection of flashing for damage is similar to the inspection of metal roofing. As with roofing, the damage may have been caused by high winds or by inadequate installation. If the damage is caused by wind, look for broken seams or fasteners. If the damage is caused by inadequate installation (inadequate expansion joints or improper fastening), look for broken seams and cracks in the metal.

7-16. Suppose that you have a work order to repair damaged fascia and gravel guard flashing such as that shown in figure 19. You find that two sections have pulled loose from the ¾-inch strip at the bottom but are still being held at the top by fasteners (nails). You must first determine the amount of damage by inspecting the expansion joints, the soldered joints and seams, and the bottom strip for looseness, breaks, and bends. Check the fascia board for damage or deterioration so that you can determine if assistance from the carpenter shop is necessary. Check the metal where it is fastened to the roof deck for evidence of water leaks. If the gravel guard has been bent up and pulled loose from the roof deck, the roofing will probably need repairing by using hot asphalt and gravel.

7-17. When examining flashing such as that used with gables, valleys, ridge caps, and chimneys, look for loose fasteners; sealing compound that needs replacing; soldered joints that need resoldering; and bends, breaks, and cracks in the flashing.

7-18. *Gutters.* Gutters, such as those shown in figure 20, may be damaged by wind, ice, hail, expansion, or contraction; they also can be damaged by falling objects or by moving vehicles which accidentally hit them. The amount of inspection for this type of damage will depend largely on the extent of the damage. For example, wind damage will usually result in loose or broken gutter hangers; if the damage is minor, only the hangers will need to be tightened or replaced. If the damage is greater and several hangers have pulled loose, you may find bent sections of gutter and damaged joint connections.

7-19. In localities where there is snow and ice, gutter damage can be caused by ice forming on the eaves of the roof, in the gutter, or in the downspout. Sometimes a formation of ice or snow may slide off a roof and damage the gutter. Excessive ice buildup will usually cause the hangers to break and the gutter to sag or fall. When this happens, the seams and joint connections are likely to give way and should be examined for damage.

7-20. Expansion and contraction of gutters may cause damaged joint connections and sealants, loose hangers and fasteners, and broken solder joints. Damage caused by a truck or a fork lift will usually result in bent gutter components. This can range from minor damage such as a simple dent in one joint to major damage that completely flattens one or or more joints. If it is a small bend, check the joints near the bend for breaks, the hangers for loose fasteners and bends, and the entire section of gutter for alignment. Larger damaged areas should be checked for breaks in the seams, joints, and hangers. Check the hangers and joints on either side of the damaged area to see if they have broken loose.

7-21. *Downspouts.* Damage to downspouts is usually caused by circumstances similar to those that cause damage to gutters. When downspouts are damaged by wind, examine the damaged area for broken joints, loose or broken hangers, and loose joint connections. If a downspout has been bent or mashed or if the metal has been torn, make a thorough examination of the joints, seams, joint connections, and hangers. Inadequate provision for expansion and contraction will result in loose fasteners and hangers. Damage caused by trucks, fork lifts, or lawn mowers will usually bend or flatten the downspout at the point of impact.

necessary to disassemble the turbine. A squeaking turbine indicates that the bearings are worn or need a lubricant. In a situation like this, you should check both the bearings and the shaft.

7-11. *Metal roofing.* When metal roofing is damaged by wind, the metal may be pulled away from the fasteners, or the fasteners may be pulled away from the roof deck. Damage such as buckling and breaks in the metal may be caused by inadequate expansion joints. This will indicate that adequate provision for expansion and contraction should be made when the repairs are made. Check the metal closely for small cracks, which are sometimes hard to see. Wind and expansion are the

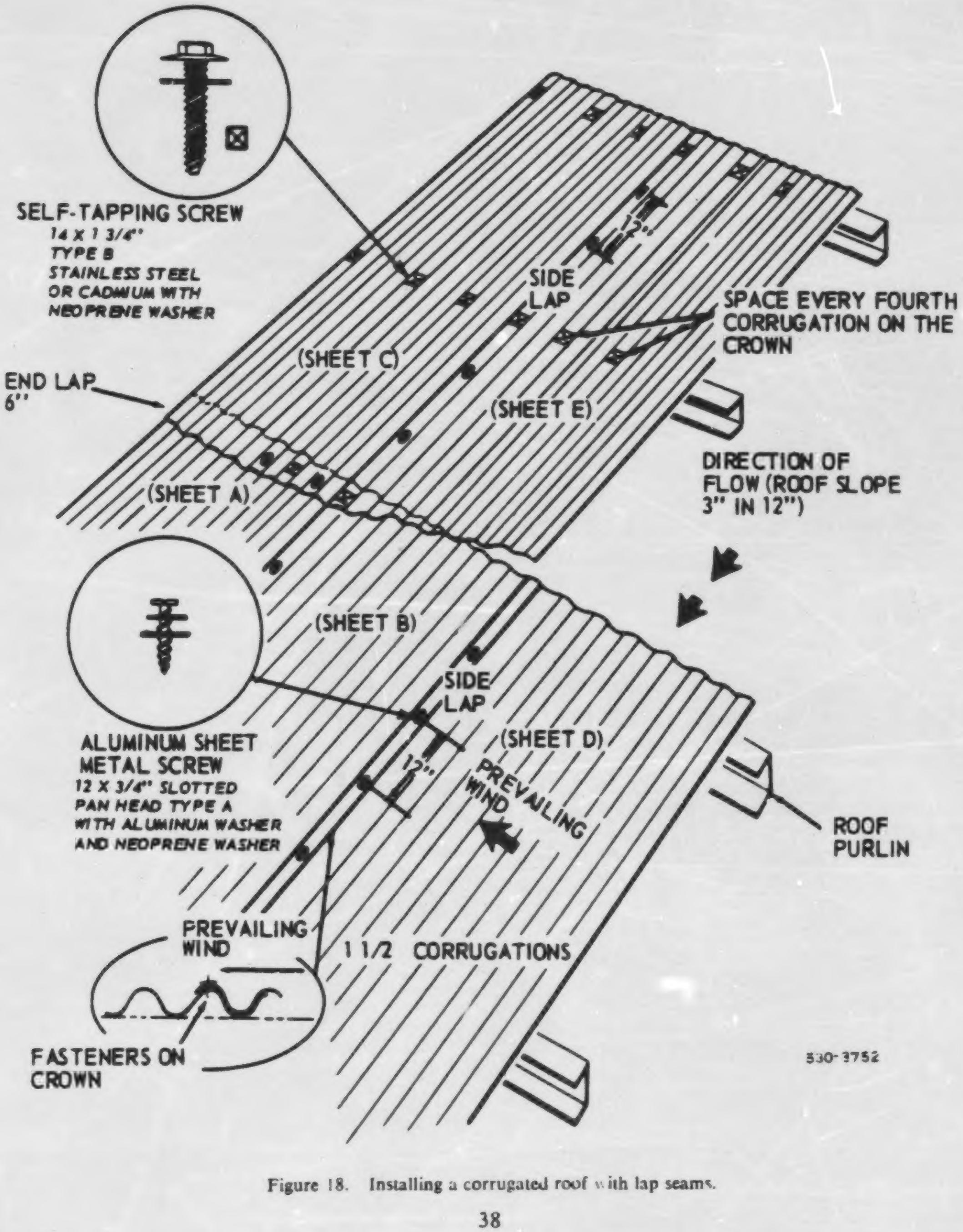

SELF-TAPPING SCREW
14 X 1 3/4"
TYPE B
STAINLESS STEEL
OR CADMIUM WITH
NEOPRENE WASHER
12"
SIDE LAP
SPACE EVERY FOURTH CORRUGATION ON THE CROWN
(SHEET C)
END LAP 6"
(SHEET E)
DIRECTION OF FLOW (ROOF SLOPE 3" IN 12")
(SHEET A)
(SHEET B)
SIDE LAP
(SHEET D)
ALUMINUM SHEET METAL SCREW
12 X 3/4" SLOTTED
PAN HEAD TYPE A
WITH ALUMINUM WASHER
AND NEOPRENE WASHER
12"
PREVAILING WIND
ROOF PURLIN
PREVAILING WIND
1 1/2 CORRUGATIONS
FASTENERS ON CROWN
530-3752

Figure 18. Installing a corrugated roof with lap seams.

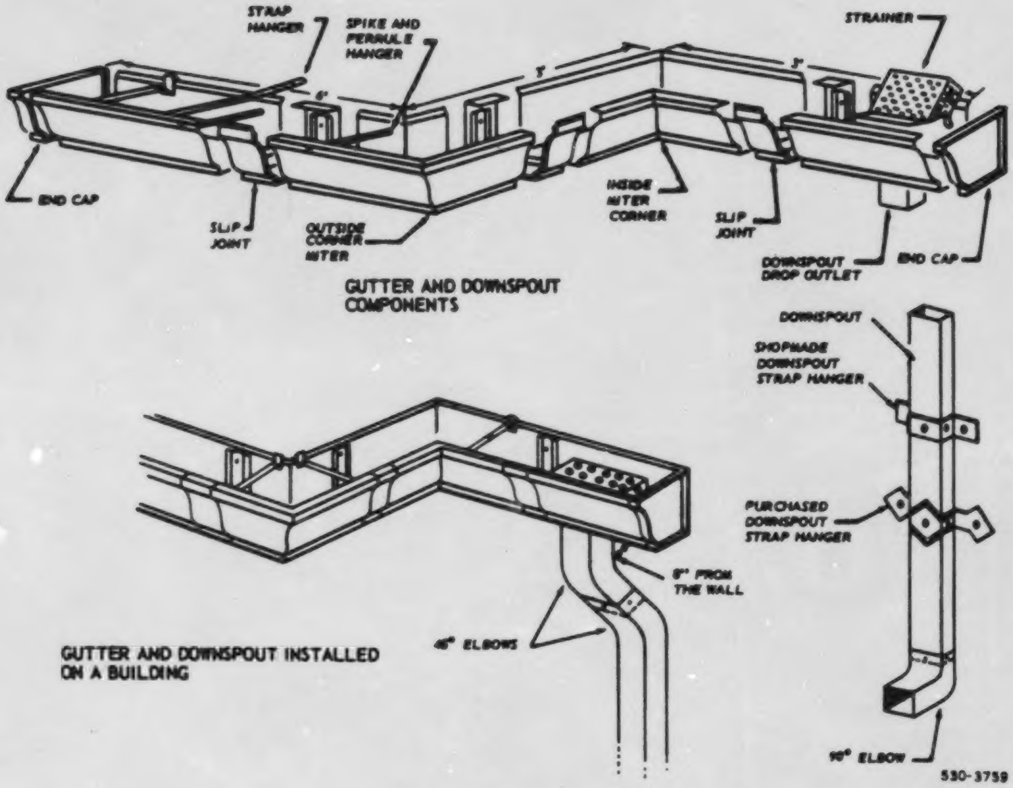

STRAP HANGER
SPIKE AND FERRULE HANGER
STRAINER
6'
3'
3'
END CAP
SLIP JOINT
OUTSIDE CORNER MITER
INSIDE MITER CORNER
SLIP JOINT
DOWNSPOUT DROP OUTLET
END CAP
GUTTER AND DOWNSPOUT COMPONENTS
DOWNSPOUT
SHOPMADE DOWNSPOUT STRAP HANGER
PURCHASED DOWNSPOUT STRAP HANGER
8" FROM THE WALL
45° ELBOWS
GUTTER AND DOWNSPOUT INSTALLED ON A BUILDING
90° ELBOW
530-3759

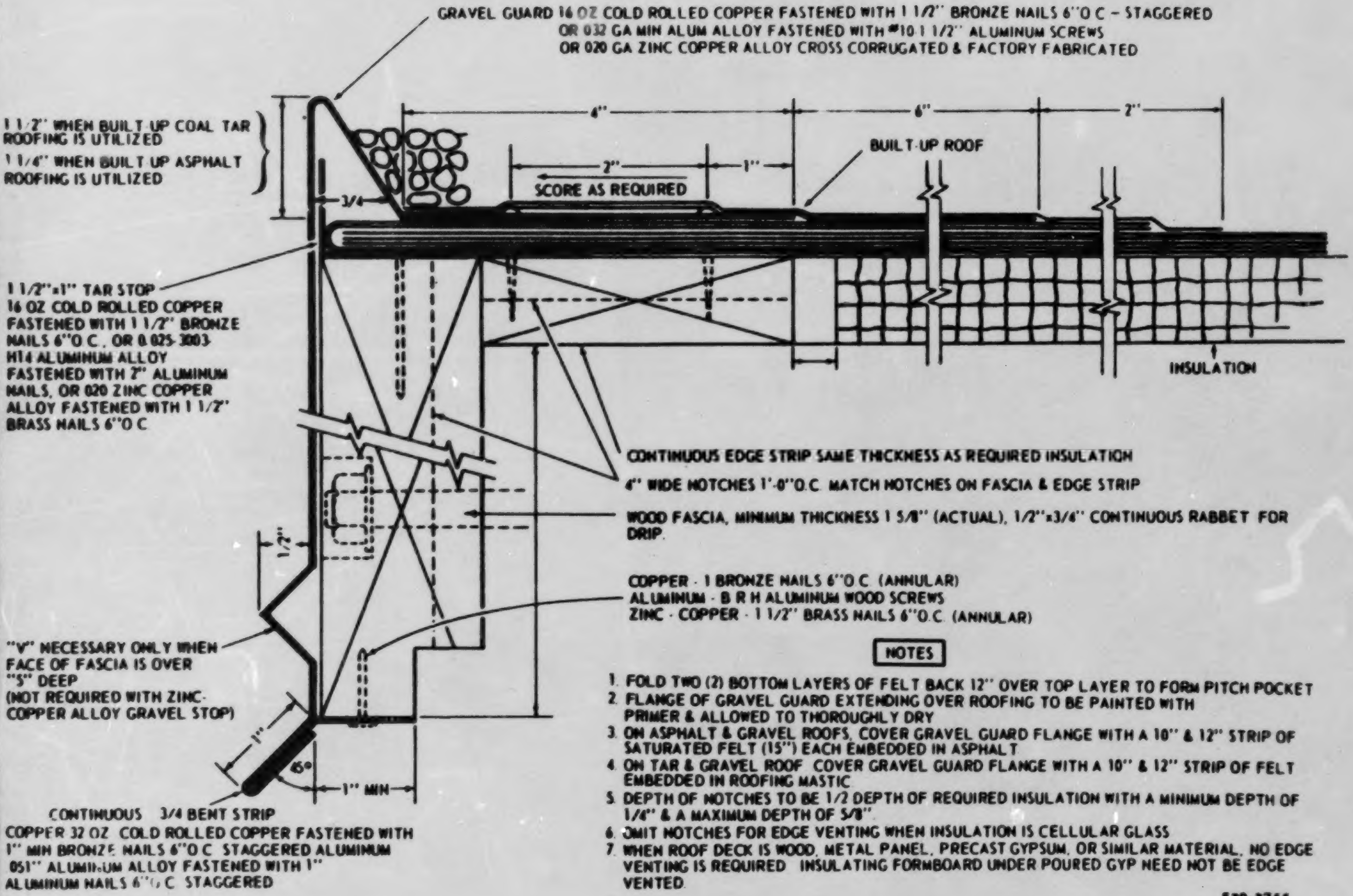
Figure 20. Gutter and downspout components.

This will result in bent metal, broken joint connections, and broken hangers. Examine the metal for cuts, holes, or formed corners that will need straightening or replacement. Also examine the seams and joint connections on each side of the damaged area.

7-22. *Awnings and canopies*. Damage to awnings and canopies can be caused by wind, hail, or falling objects. Wind often pulls the fasteners loose at the points where the panels fit together or where the awning (or canopy) is attached to the building. If the panel fasteners fail, the panels can be bent. If the attaching fasteners fail, the canopy can fall or become misaligned. Small hail can make small, round dents in the metal, especially if the canopy is made of aluminum. Larger hail can make big dents as well as holes in the metal panels. Falling objects can make dents and holes and can cause fasteners to pull loose.

7-23. When awnings or canopies have been blown away from buildings, you can expect the metal panels to be bent, some of the fasteners to be sheared, and the component to be out of alignment. Check the fasteners and determine which need to be replaced. Check the panels to see if they should be straightened, patched, or replaced. Check the alignment to see what needs to be done.

7-24. **Inspecting for Deterioration.** By definition, deterioration means a gradual impairment which makes something inferior in quality or value. Deterioration in metals is usually due to corrosion from moisture, chemicals, or both. Moisture that is present in the air or in the form of rain or snow causes corrosion to such sheet metal assemblies as stacks, ventilators, gutters, downspouts, and metal roofing. In coastal areas, salt is especially harmful to metals because it accelerates the corrosive action. Heated exhaust gases from furnaces and heaters are corrosive to the stacks that are used to carry the fumes from buildings. Exhaust fumes from acid tanks such as those used in plating shops, are corrosive to the ventilating ducts and exhaust ventilators used to carry the fumes from buildings. The overflow from water tanks and cooling towers is corrosive to the metal roofing, gutters, and downspouts that carry the drainage. The moisture and chemicals that are contained in foods and cleaning agents are corrosive to the serving line equipment used in dining halls. Water and cleaning agents are corrosive to the metal used in shower stalls. Condensed mois-


GRAVEL GUARD 16 OZ COLD ROLLED COPPER FASTENED WITH 1 1/2" BRONZE NAILS 6"O C – STAGGERED OR 032 GA MIN ALUM ALLOY FASTENED WITH #10 1 1/2" ALUMINUM SCREWS OR 020 GA ZINC COPPER ALLOY CROSS CORRUGATED & FACTORY FABRICATED
1 1/2" WHEN BUILT UP COAL TAR ROOFING IS UTILIZED
1 1/4" WHEN BUILT UP ASPHALT ROOFING IS UTILIZED
3/4
4"
6"
2"
2"
1"
SCORE AS REQUIRED
BUILT-UP ROOF
INSULATION
1 1/2"x1" TAR STOP 16 OZ COLD ROLLED COPPER FASTENED WITH 1 1/2" BRONZE NAILS 6"O C., OR 0.025-3003-H14 ALUMINUM ALLOY FASTENED WITH 2" ALUMINUM NAILS, OR 020 ZINC COPPER ALLOY FASTENED WITH 1 1/2" BRASS NAILS 6"O C
CONTINUOUS EDGE STRIP SAME THICKNESS AS REQUIRED INSULATION
4" WIDE NOTCHES 1'-0"O.C. MATCH NOTCHES ON FASCIA & EDGE STRIP
WOOD FASCIA, MINIMUM THICKNESS 1 5/8" (ACTUAL), 1/2"x3/4" CONTINUOUS RABBET FOR DRIP.
1/2"
COPPER - 1 BRONZE NAILS 6"O.C. (ANNULAR)
ALUMINUM - B R H ALUMINUM WOOD SCREWS
ZINC - COPPER - 1 1/2" BRASS NAILS 6"O.C. (ANNULAR)
"V" NECESSARY ONLY WHEN FACE OF FASCIA IS OVER "5" DEEP (NOT REQUIRED WITH ZINC-COPPER ALLOY GRAVEL STOP)
1"
45°
1" MIN
CONTINUOUS 3/4 BENT STRIP
COPPER 32 OZ COLD ROLLED COPPER FASTENED WITH 1" MIN BRONZE NAILS 6"O C STAGGERED ALUMINUM 051" ALUMINUM ALLOY FASTENED WITH 1" ALUMINUM NAILS 6"O C STAGGERED

NOTES

1. FOLD TWO (2) BOTTOM LAYERS OF FELT BACK 12" OVER TOP LAYER TO FORM PITCH POCKET
2. FLANGE OF GRAVEL GUARD EXTENDING OVER ROOFING TO BE PAINTED WITH PRIMER & ALLOWED TO THOROUGHLY DRY
3. ON ASPHALT & GRAVEL ROOFS, COVER GRAVEL GUARD FLANGE WITH A 10" & 12" STRIP OF SATURATED FELT (15") EACH EMBEDDED IN ASPHALT
4. ON TAR & GRAVEL ROOF COVER GRAVEL GUARD FLANGE WITH A 10" & 12" STRIP OF FELT EMBEDDED IN ROOFING MASTIC
5. DEPTH OF NOTCHES TO BE 1/2 DEPTH OF REQUIRED INSULATION WITH A MINIMUM DEPTH OF 1/4" & A MAXIMUM DEPTH OF 5/8".
6. OMIT NOTCHES FOR EDGE VENTING WHEN INSULATION IS CELLULAR GLASS
7. WHEN ROOF DECK IS WOOD, METAL PANEL, PRECAST GYPSUM, OR SIMILAR MATERIAL, NO EDGE VENTING IS REQUIRED INSULATING FORMBOARD UNDER POURED GYP NEED NOT BE EDGE VENTED

530-3744

Figure 19. Fabrication detail for fascia and gravel guard flashing.

ture on an air-conditioning duct that is not adequately insulated is also a source of corrosion to the metal. In each of the above cases, corrosion can be minimized by the use of metals that are resistant to the type of corrosive agent present.

7-25. *Stages of corrosion.* In figure 21 you can see some of the stages of corrosion which have occurred to a piece of metal. View A shows light surface corrosion where the painted, galvanized, or porcelain surface has been worn off and the metal is just starting to corrode. Light surface corrosion can be stopped by removing the discolored spots of corrosion and resealing the area. View B shows moderate corrosion which is in the blistered and pitted stages. The blister shown in the illustration is on the painted surface, and the pitting is in the metal under the paint. The pitting is concealed by the blister but will continue to grow deeper unless the blister is removed and the pitted spot is cleaned out and sealed with solder, paint, or other sealants. To help you identify areas where corrosion is taking place under paint, blisters like this will usually be stained with rust-colored streaks. When this type of corrosion is discovered, remove the blister with a scraper and clean the surface of the metal in and around the pitted area. In some cases, such as when the corrosion is on light gage metal, it may be better to cut out the corroded area and make a patch for the hole. This should be followed with sealing or refinishing to prevent the corrosion from recurring.

7-26. In view C of figure 21 you can see an example of severe corrosion which has flakes, pits, and holes. Metal in this condition is weak and will probably give way if you press on it. When you discover a small area such as this, it may be desirable to cut out, patch, and reseal the area. If several spots of severe corrosion are discovered or if the corroded area is larger than 3 inches in diameter, the chances are that the remaining metal in the component is corroded enough to warrant making a new component.

7-27. *Ducts.* Ducts that are exposed to corrosive conditions will have pits on the inside or outside of the component. If the corrosion is caused by condensation, the pits will usually be near the register outlet, which may also be corroded. An air-conditioning duct with torn insulation will probably be corroded, because moisture will form at the uncovered spot. To determine the amount of corrosion, clean the damaged area with a scraper and see how deep the corrosion has penetrated. If the penetration is deep and the metal looks something like that shown in view C, you will know that the metal is weak and, depending on the size and number of spots, the damaged area should be patched or the entire component replaced. The depth of the pits and the extent to which the corrosion has weakened the metal depend a lot on the thickness of the duct. For example, if the metal is 26 gage, it won't take a very deep pit to extend through the metal. Also be sure to check the surrounding area for corroded spots.

7-28. Ducts that are corroded from exposure to acid fumes may show very little damage from the outside. This is especially true if the duct is painted. When visually inspecting this kind of duct, be sure to look for blisters and for any signs of the discoloration which may reveal a corroded area. When blisters are found, they should be scraped and the extent of the damage determined. It is possible for a duct that carries acid fumes to be so corroded on the inside that you can easily punch holes through it with your finger. When this condition is discovered in one location, be sure to inspect the entire system. It will probably be necessary to replace the entire duct system.

7-29. As an example, suppose you have been assigned to repair a corroded vent cap on an exhaust ventilator in the plating shop. Your examination of the ventilator reveals that it is also corroded and that the fasteners holding the vent cap have pulled away from the metal. This is a good clue that there is also corrosion in other parts of the ventilator and the duct system; look inside the system and check the extent of the damage. Test the metal by scraping or bending to see how much deterioration has taken place. If the inside of the ventilator has severe corrosion, continue the inspection to other components of the duct system. Scrape any blisters; determine the depth of the pits; and, if necessary, press with your fingers in suspected areas. Remove the registers or grilles and visually inspect the inside of the duct. Observe the shanks of screws used in the duct to determine the extent of the corrosion. If the threads are deteriorated, it is enough evidence that the duct is also corroded.

7-30. *Shower stalls.* Most corrosion in shower stalls made of sheet metal is found in the bottom panels and the side panels near the bottom. When you are inspecting shower stalls for corrosion, look for any signs of corrosion. You may find only the discolored spots of light surface corrosion or the blisters which indicate moderate corrosion and pitting. Then again, you may find holes that indicate severe corrosion. When any of these signs are discovered, use the methods already described in this chapter to determine how severe the damage is and what must be done to make the repair.

7-31. *Roofing and flashing.* Check for deterioration to roofing and flashing by first looking for the signs of corrosion. If the roofing and flashing are made of galvanized metal, look for rust-colored streaks, which are a sure sign that corrosion is taking place somewhere. Don't be fooled if these streaks are found at a place which is not corroded. Follow the streaks to the source and you will probably find blisters, pits, and perhaps holes. Once

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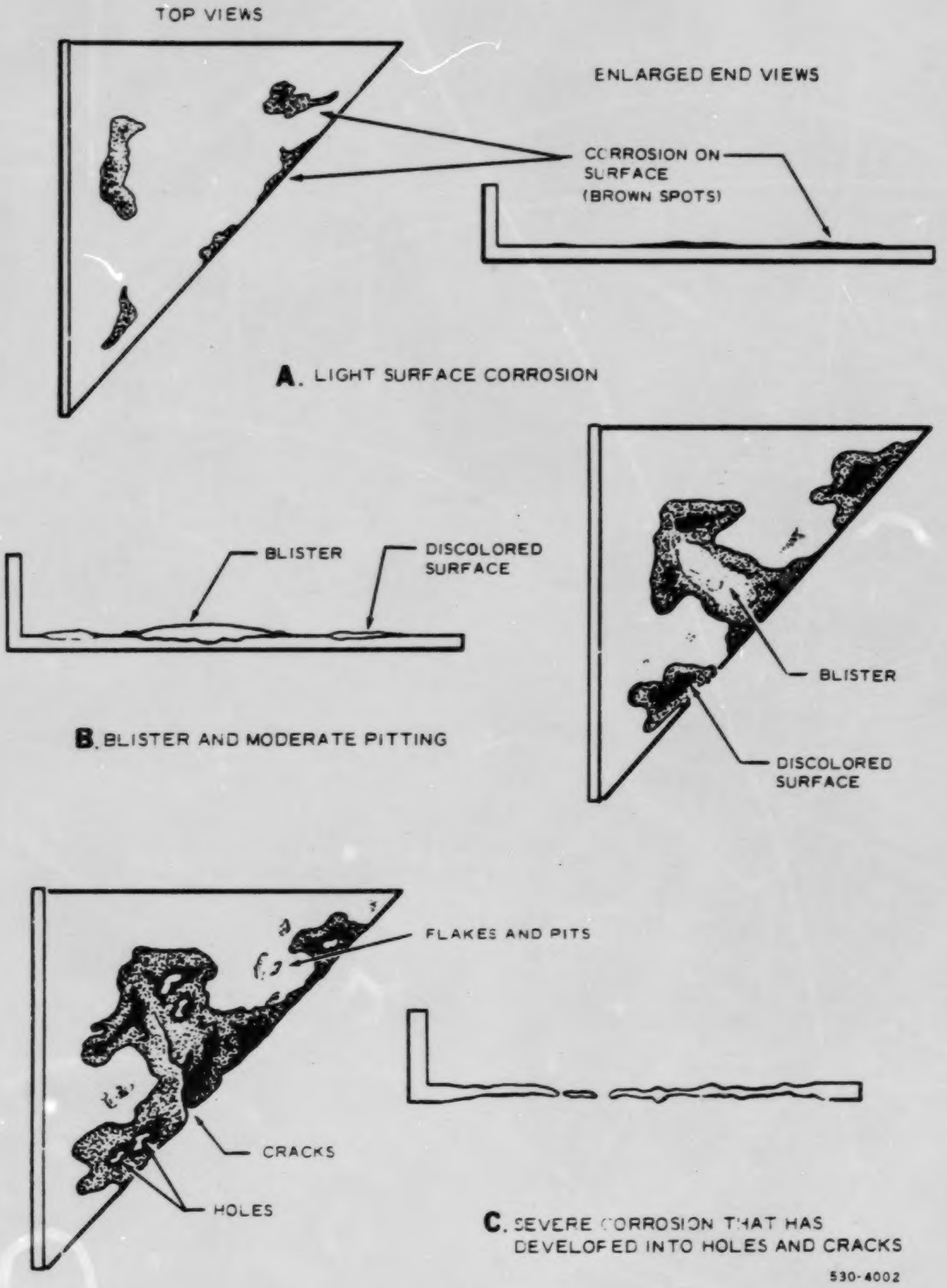
TOP VIEWS
ENLARGED END VIEWS
CORROSION ON SURFACE (BROWN SPOTS)
A. LIGHT SURFACE CORROSION
BLISTER
DISCOLORED SURFACE
B. BLISTER AND MODERATE PITTING
BLISTER
DISCOLORED SURFACE
FLAKES AND PITS
CRACKS
HOLES
C. SEVERE CORROSION THAT HAS DEVELOPED INTO HOLES AND CRACKS
530-4002

Figure 21. Stages of corrosion.

4. The pattern in figure 64 is for a round duct duct joint with a grooved seam. The 180° bends for the seam must be turned opposite sides so the seam will fit together when the joint is assembled. (7-5. 31; 2-9; Figs. 64. 12)
5. The piece should be 13½" x 26⅛". The length of the joint is 12" + 1½" (allowance for the slip joint), and the stretchout is 25⅛" + 1" (allowance for the grooved seam). (7-5; 6-50; Figs. 60. 64)
6. *a.* The triangulation method is used for transitions because they have sides that are not parallel nor do they meet at a common point. The true length of the slanting sides must be determined. (7-6; Fig. 65; and Vol. 1)
   b. The pattern stretchouts are the true heights of the slanting sides and are 1/16 inch longer than in the plan and elevation views. (7-6. 6-46; Fig. 65)
   c. The ½-inch "straight" is used to return the slanting sides parallel with the duct so that the S-and-drive slips will fit properly. A similar example is shown in figure 31 for S-slips. (7-6; Figs. 65. 31)
   d. The transition patterns can be easily cut from sheet 6 (Fig. 59) with squaring shears. (7-19; Figs. 59. 65)
   e. Notches for each corner of the top and bottom patterns include a 90° square notch for the 1-inch Pittsburg allowance. a 90° square notch for the ½-inch "straight" allowance. and a 45° slant notch for the S-slip connection allowance. (7-21. 23; Fig. 65)
   f. This transition is made in four pieces and does not have corner bends because each corner has a Pittsburg lock seam. (7-32. 27; Fig. 65)
7. See figure CRE Ans–4. (7-6–8. 4. 23; Figs. 57. 65. CRE Ans–4; and Vol. 1)
8. *a.* Without allowances. the pattern should be 12" x 8". (7-9; Figs. 60. 66)
   b. With allowances included. the pattern should be 16" x 12". (7-9; Figs. 60. 66)
   c. The metal should be turned over and bent up on the cross brake lines. (7-9. 28. 34; Figs. 60. 66)
9. See figure CRE Ans–5. (7-9. 24. 34; Figs. 60. 66. CRE Ans–5)
10. *a.* The heel radius for the 8-inch elbow is 16 inches. (7-10; Figs. 60. 61. 68; and Vol. 1)
   b. Gores I and V are half-gores. Gores II. III. and IV are whole gores. (7-10; Fig. 68; and Vol. 1)

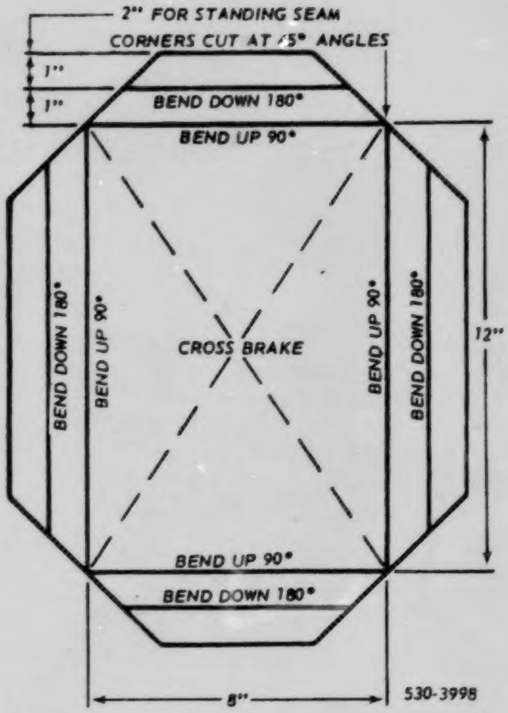

Figure CRE Ans–5. End cover pattern for joint 15 of trunk line C.

   c. The working line for the 8-inch elbow stretchout is 25⅛ inches long. (7-11; Fig. 68; and Vol. 1)
   d. The length of the element lines on the stretchout is determined by the length of the element lines from the plan view as they pass through the miter lines of gore I. (7-11; Fig. 68)
   e. The allowance for the slip joint will be on gore I for the 8-inch elbow the same as for the 6-inch elbow. (7-20; Figs. 68. 70)
11. See figure CRE Ans–6. (7-10. 11. 12. 25; Figs. 57. 68. CRE Ans–6; and Vol. 1)
12. See figure CRE Ans–7. (7-10–12. 20. 25; Figs. 70. CRE Ans–6. CRE Ans–7)
13. Straight snips are not needed. In this job. straight snips are used principally for notching. The round duct joints do not need notching. Also. because of the extensive number of cuts to be made. squaring shears will be used instead of hand-operated straight snips. (7-31. 22; FO 1; and Vol. 2)
14. The ridges will be on the outside of the transition. (7-32. 2; Fig. 65)
15. The Pittsburg lock forming machine. slip

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the spots are located, scrape the surface, determine the extent of the corrosion, and determine what repair is necessary.

7-32. Metal roofs with exhaust ventilators or evaporative coolers should be checked closely for corrosion in the areas where these units are installed. Corrosive vapors may have been exhausted from the ventilator, or the moisture from the cooling unit may have caused deterioration to the metal roof and flashing around the ventilator.

7-33. *Stacks and ventilators.* When inspecting stacks and ventilators for corrosion, remember that they are exhausters and are exposed to corrosion from the inside as well as the outside. Closely check these components for deterioration if there are any rust-colored streaks on the metal; be sure to follow the streak to its source. If the surface has been painted, be sure to look for blisters.

7-34. *Gutters and downspouts.* Gutters and downspouts, like metal roofing, will corrode when exposed to moisture and/or chemicals. When installed properly, gutters should drain completely; however, leaves and trash may cause water to stand in a gutter for extended periods of time. This will eventually cause deterioration; inspect these locations for damage. Gutters that have been exposed to chemicals from any source will corrode along the entire gutter and downspout; be sure to check thoroughly.

8. Determining Limitations and Methods of Repair

8-1. By definition, the word "repair" means to put back in good condition after damage. In this section we will discuss what repair limitations must be considered, what repair methods should be used, and how the problem-solving technique can be applied. You should recall from an earlier chapter that the problem-solving technique includes defining the problem, establishing objectives, gathering facts, weighing the facts, taking action, and evaluating the action taken.

8-2. **Limitations of Repair.** Determining limitations of repair requires several items in addition to using the problem-solving techniques. The additional items include type of construction, location, cost, equipment, personnel, and availability of materials.

8-3. *Type of construction.* The construction of buildings is divided into three categories which you must consider when determining limitations of repair. These categories are permanent, semipermanent, and temporary. Permanent buildings have a life expectancy of 25 years or more with normal maintenance. Semipermanent buildings have a life expectancy of 10 to 25 years with normal maintenance. Temporary buildings have a life expectancy of less than 10 years with normal maintenance. As an example, a temporary building has a gutter that is corroded to the extent that it needs replacing. From your knowledge of metals, you have determined that copper should not be used, because a copper gutter has life expectancy longer than the life expectancy of the building. The replacement gutter should be made of galvanized metal, which will serve the purpose for the length of time needed and will be less expensive.

8-4. *Location.* The location of a repair job is one of the limiting factors that must be considered when determining the method of repair. For example, a patch that is to be located in a prominent place on a stainless steel serving line unit should be made of the same metal, made flush with the surface, and be as inconspicuous as possible. However, if the damage is underneath or behind the serving line unit, the patch can be made with less emphasis on appearance. Thus the repair could be made more quickly and at lower cost. Use of scaffolds, which are necessary for many repair jobs, represents another example of the limiting factor of location. Additional time will be needed to set up the scaffold, to reposition the scaffold as the job progresses, and to return the scaffold to the storage area when the job is completed.

8-5. *Cost.* Cost is one of the limiting factors that must be considered when determining the method of repair. Since the cost of a job is affected by time and materials required, you should determine the most economical methods. To do this, consider such things as the extent of damage (or deterioration), cost of materials, man-hours required, type of construction, and location of the job. If a component is badly damaged and requires a lot of straightening, it may be more economical to replace it than to patch it. For example, suppose you are to repair a gutter which is corroded in several places and has holes through the metal. You should consider whether repair by patching will extend the life of the gutter enough to justify the cost of repair or whether replacement would be more economical. In this case, since the corrosion is severe, it is likely that further repairs would have to be made later. Replacement would probably be more economical in the long run.

8-6. *Equipment.* Equipment is one of the limiting factors when determining methods of repair. For example, suppose you are to repair a component that has several heavy-gage metal parts which must be fabricated. Examine the damaged component to determine if your shop has fabricating equipment with sufficient capacity to accommodate the thickness and shape of the replacement parts. However, cutting, forming, and folding equipment are not the only equipment factors that should be considered. The location of the job and the installation of the component should also be taken into consideration. Equipment such as scaffolds and portable platforms may be needed to install the component.

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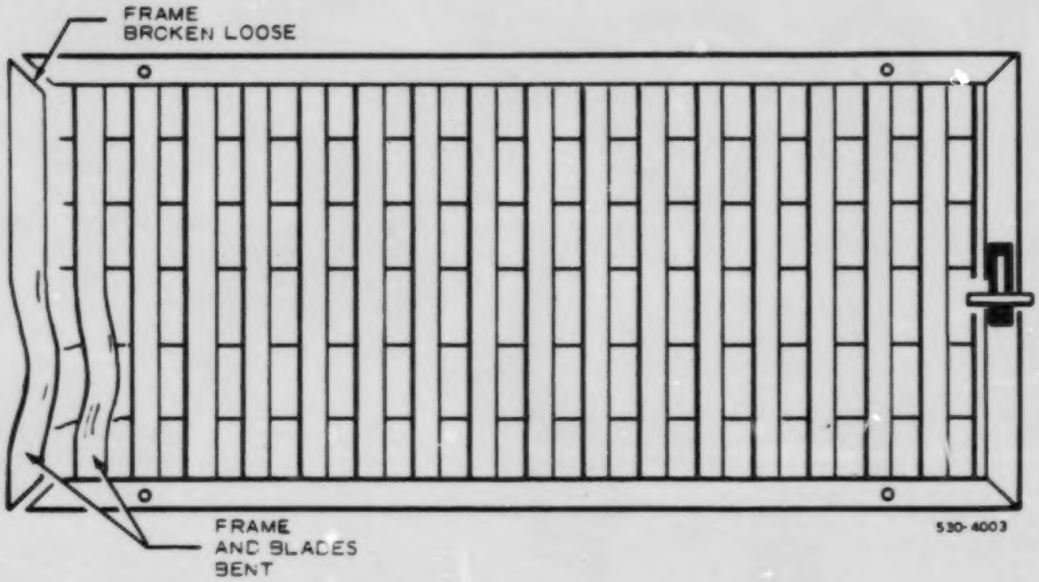

Figure 22. Damaged register.

8-7. Suppose that you have to repair the flashing which is located above the large doors of a hangar. The doors are 65 feet high and will require equipment that will allow the men to work safely at that height. You decide to use a portable platform lift which is equipped with a guardrail around the working platform. Obtaining and using this elevated platform will require coordination between you and the hangar supervisor, because aircraft are usually in the hangars and may need to be moved out of the way. You and the hangar supervisor should make arrangements for the doors to be worked on without interfering with aircraft repair operations.

8-8. *Personnel.* The number of qualified personnel available in the sheet metal shop or in the crew is also a limiting factor when determining methods of repair. You must consider how big the job is, how many men will be needed, how many men you have, and the number of jobs already assigned to the shop. It is possible that the job may be too large to do at the present time without pulling men off other jobs. Another example is a job that is complicated and has parts that are difficult to fabricate. It will be necessary to assign the right man to the job. Assigning a man to a job that is within his capabilities is one of the supervisory techniques of good human relations.

8-9. *Availability of materials.* Materials needed to complete a job are just as important to consider as the other limiting factors when determining methods of repair. If a repair job requires the fabrication of a component, you must have the material available at the right time. Suppose that a trouble call assignment has been made and you have inspected the job and determined that a replacement component needs to be fabricated. It will be necessary to determine how much material will be needed and whether enough material is on hand. If the job is large and will require more material than is on hand, you should make out a materials list and turn it in to the materiel control section so that a work order (AF Form 327) can be prepared and materials can be ordered for the job.

8-10. The type of materials to be used in the fabrication of a component is a limiting factor when determining the availability of material for a job. For example, suppose that a repair job requires aluminum sheets. You will need to know how many sheets are required, the thickness of the material, and the type of aluminum required. From this information you can determine whether the aluminum is available in bench stock or if it must be ordered. Other materials that should be considered include such items as nuts, bolts, screws, rivets, hangers, braces, and insulation.

8-11. **Methods of Repair.** Repair to sheet metal components includes such methods as refastening, cleaning and resealing, patching, straightening, and replacing. These methods can be used to repair any of the sheet metal components that we have discussed in this course. When a repair job is assigned, a determination must be made as to which of these methods (or combination of methods) to use. You will find that problem-solving and limitations of repair (discussed in the preceding paragraphs) must be used. These limitations include the type of construction, location of job, cost, equipment, personnel, and availability of materials. In the following paragraphs we will use examples of repairing registers, stacks, roofing, flashing, gutters, and downspouts to show how the various methods of repair can be applied to sheet metal components.

8-12. The register shown in figure 22 has been damaged by a fork lift in a warehouse. The frame of the register is bent, the spot welded corners are broken loose, and some of the blades are bent. A work order has been issued to repair the damaged register. Let's see how the problem-solving technique can be used to determine the method of repair.

a. The problem is a damaged register.

b. The objective is to determine what method to use in repairing the register.

c. Facts are gathered by inspecting the damaged register and getting such information as the type of construction; location of the damage; and the availability of equipment, personnel, and materials. In this example, the frame and blades of the register are made of painted 20-gage sheet iron. The frame has spot welded corners. The damages are shown in figure 22. The bent pieces can be straightened reasonably well with a bench vise and wood blocks. The shop has a spot welding machine that can be used to refasten the corners of the frame. The repaired register is to be reinstalled in the warehouse where it was damaged.

d. With the facts gathered, the next step is to determine whether to straighten and refasten, to fabricate replacement parts, or to purchase a new register. In this example, the decision is to straighten the frame and blades, refasten the corners with spot welds, and reinstall the unit in the warehouse. This decision is based on the following criteria: (1) The type of construction will permit the frame to be straightened and spot welded. (2) The register is located in a warehouse, therefore the appearance is not critical. (3) Equipment for the job is available. (4) Qualified repair personnel are available. (5) No additional materials (except paint) are required. (6) The estimated cost for straightening and spot welding is one-half the cost of a new register.

e. The final step of the problem-solving technique is to take action. Repair the register and inspect it to see if the unit has been satisfactorily repaired and reinstalled.

8-13. Stacks such as the one shown in figure 16 will usually need repair or replacement because of the corrosive action of the heat and fumes that pass through the assembly and because of the moisture and cold that are present on the outside of the assembly. The components of the stack assembly that will most often need repair or replacement are those located on the outside of the building. High winds sometimes blow a stack assembly over and damage some of the parts, necessitating repair and reinstallation. Hail also may damage stack components to the extent that repair or replacement may be necessary. You will find that damages due to wind or hail are not difficult to detect, and extent of repair necessary is not difficult to determine. You will also find that the extent of corrosion damage to stacks will be somewhat difficult to determine, because it may be any of the three types of corrosion shown in figure 21. The extent of light or moderate corrosion is the most difficult to determine, because it will be on the inside of the stack. If discoloration and light corrosion are detected soon after installation of new stack components, the cause may be traced to inadequate height and location of the vent cap. Inadequate height or location will result in improper airflow (draft) from the vent cap, thus causing excessive corrosion to the inside and outside of the vent cap.

8-14. It is common for a corroded vent stack not to be reported for repair until the corrosion has become as severe as that shown in view C of figure 21. When the upper components of a stack assembly have severe corrosion damage they will require replacement. Sometimes when severe damage has occurred to the vent cap and upper stack, the roof jack, flashing, or collar may have only light or moderate corrosion and can be repaired by scraping and sealing with sealant or paint. In some cases, patching may be necessary; however, if the patching will take more time than that required to make a new component, it would not be economical to use the patching method.

8-15. Metal roofing and flashing that have light surface corrosion can be repaired by cleaning and painting. In cases where the corrosion has caused blisters and moderate pitting, the damaged area can be repaired by cleaning and sealing. Roofing and flashing that have small areas of severe corrosion damage will require patching and sealing. If the damaged area is large the entire area will need to be replaced.

8-16. From the preceding examples you can see that damaged or corroded sheet metal can be repaired by several methods or combinations of methods, such as cleaning and resealing, patching, straightening, refastening, and replacing. The problem-solving method can be used to determine which method(s) to use.

MODIFICATIONS

Chapter 4, pages 47-66 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 5

Inspections and Evaluations

IN AN EARLIER chapter of this volume you learned how layout, fabrication, and installation of sheet metal components were inspected for accuracy and quality of workmanship. From your study of the previous chapters you recall that the sheet metal shop supervisor's job was not limited to fabrication and installation inspections alone. This is why we need to discuss the inspection of work orders, work areas, equipment, tools, and supplies as they pertain to shop activities. In conjunction with all this we need to emphasize the importance of inspections. It should also be pointed out that upon completion of any inspection you should evaluate your findings to determine the need for changes and improvements. For this reason we are including a discussion on inspection and evaluation.

2. Inspections and evaluations serve as a means of assurance that your shop is operating in accordance with approved procedures as outlined in the controlling directives for your shop. Without inspections, a shop is apt to become inefficient, thus resulting in a loss of production, unsafe working conditions, and lack of good supply discipline.

3. The information contained in this chapter will help you to maintain high-level production and quality maintenance in conjunction with the shop mission and your assigned responsibilities. This information will contribute to a safe place to work, safe equipment to use, and available supplies in the proper quantities and location. If you learn this information, you will be able to inspect *any* civil engineer maintenance and repair sheet metal shop for proper compliance with manuals, regulations, and local directives.

13. Inspection Procedures

13-1. Work orders are inspected in the shop before work is started to determine if the work order is complete and accurate. It is also necessary to inspect the shop work areas to see that floors are clear of metal and other hazardous material, that equipment and tools are safe to use, and that combustible materials are properly stored. Supplies are inspected to see that the supply levels are properly maintained and that all supplies are stored properly. A study of inspection procedures is included in this section, and we will start with work orders.

13-2. **Work Orders.** When a work order is received by the shop, it is inspected for work description, priority, authorization, materials, and drawings. This is done to detect any discrepancies before the job is started.

13-3. Authorization is the first thing to check, since the work order must be initialed or signed by the chief of programs division before it is considered valid. You will recall from the preceding chapter that the shop copy of the work order is usually initialed. When the work order is found to be valid, check the priority. Now, refer to figure 23 in Chapter 4, and you will see that the authorization official is identified in block 11 and the priority is shown in block 18 of the illustrated work order.

13-4. Using figure 23 again, check the work order number in block 2, the requesting organization in block 2, the requesting organization in block 7, and the requester in block 8. Check to see that the requester's telephone number is in block 9 and the location of the work is entered in block 20. Now check the work description in block 10, performance areas in block 23, and work plan in block 24 to make sure that all the necessary entries are entered correctly. These checks are important, since you may find that a shop has been left off the work order. It is much easier to have a shop added at this point than to add it after the work has started.

13-5. Now that you have checked the work description for all shop entries, the next step is to check the work description against the working drawing. This is necessary to assure that no items on the working drawing have been left out of the job description. At this time you should check the materials list against the drawing and work descriptions to be sure that the materials list contains all of the necessary materials. Look for such items as nuts, bolts, screws, sheet metal, angle iron, registers and insulation. Here again it is much easier

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Check List For Stationary Equipment

EQUIPMENT	Cleanliness	Markings	Lubrication	Maintenance	Operating Condition	Blades, Leaves, Rolls, Punches, Dies, Wheels	Warning Signs	Cords and Switches	Eye Protection	Guards
Power Slip Roll Forming Machine	✓	✓	✓	✓	✓	✓	✓	✓	▨	✓
Manual Slip Roll Forming Machine	✓	✓	✓	✓	✓	✓	▨	▨	▨	✓
Power Squaring Shears	✓	✓	✓	✓	✓	✓	✓	✓	▨	✓
Manual Squaring Shears	✓	✓	✓	✓	✓	✓	✓	▨	▨	✓
Circle Shears	✓	✓	✓	✓	✓	✓	✓	▨	▨	✓
Power Ring and Circle Shears	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Unishears (Stationary)	✓	✓	✓	✓	✓	✓	✓	✓	✓	▨
Power Hacksaw	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Band Saws	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Drill Press	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rotary Punch	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Bar Folder	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Cornice Brake	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Box and Pan Brake	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Pittsburg Lock Forming Machine	✓	✓	✓	✓	✓	✓	✓	✓	▨	✓
Rotary Machines	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Grinders (Stationary)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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✓ Inspection items.

▨ Items not required.

Figure 37. Inspection check list for stationary equipment

to correct an error at this time than to correct it after the work is started.

13-6. If you will stop to think for just a minute, you can see why it is necessary to check a work order very closely. Delays in supplies and support from other shops can easily be eliminated if the work order is properly checked and any discrepancy corrected before the work is started. Coordination between shops and other organizations is easily accomplished if the correct information is contained in the work order. The supervisor can plan the work efficiently and accurately when a work order is accurate and complete. No delay, such as lack of supplies or improper coordination, will interfere with completion of the job. As you have learned from the previous chapter, the work order is assigned to the shop by the scheduler. During your inspection of the work order for completeness and accuracy, you can also plan how to assign the job, designate the number of personnel needed to do the job, and determine how much assistance is needed outside of the shop.

13-7. **Work Areas.** Work area inspections include the sheet metal shop, welding shop, and the job site. A shop inspection does not necessarily occur at any given time, but the shop should be inspected daily, even while the work is being performed. The supervisor usually accomplishes the inspection; however, the working leaders as well as the workers should be on the alert for discrepancies at all times. Job sites should be inspected whenever jobs are started and, in some instances, before the job is started. Let's take a look at how work areas are inspected.

13-8. *Shop.* Shop inspections include inspecting for safety and preventive measures. Since there are so many inspection items, the following list will help you to remember some of the items to inspect.

- Cleanliness of floors and work benches
- Rag storage
- Acid storage
- Gasoline storage
- Scrap metal storage
- Fire extinguishers
- Fire exits

13-9. Starting with cleanliness of floors and work benches, you should inspect for oil, grease, dirt, and scrap metal. Grease and oil on the floor may cause someone to slip and be injured. Check behind cutting machines for scrap metal. This condition is especially hazardous to workers when they are recovering cut pieces of metal.

13-10. Rags should have two storage containers with self-closing lids that cover the containers. One container should be clearly marked for CLEAN RAGS ONLY and the other for OILY RAGS ONLY. As you continue with the inspection you should make sure that the rags are not mixed. You should also check to see that the oily rag container is emptied daily to eliminate a fire hazard.

13-11. Check the acid storage area to see that all containers are closed. The door of the acid storage area should be marked to warn personnel that acid is stored inside. The storage area should be located away from machinery or other equipment that may be damaged by the acid fumes. It is a good idea to have the acid storage area lined with lead, since lead resists acid corrosion better than most metals.

13-12. Check the shop to insure that gasoline is not stored inside the building. Gasoline should be stored in an outside storage area and in a clearly marked container. This is important for shop safety, and the identifying markings are useful when selecting unleaded gasoline for fire pots and blowtorches. Check to see that a NO SMOKING sign is posted on or near the gasoline storage area. The inside of the storage area for fire pots and blowtorches should be well ventilated to prevent gas vapors from building up in the storage area.

13-13. Check the scrap metal storage area to insure that different types of metals are stored in properly marked containers and that no scrap metal is on the floor. Also, during your inspection, check for metal waste. Many times large pieces of metal that could be used to fabricate such items as drive slips and S-slips are thrown away; therefore, a separate storage area should be designated for the larger pieces of metal.

13-14. Fire extinguishers that are ready for use are important items in any shop, especially the sheet metal and welding shops, since these shops are often exposed to open flames and hot sparks. Fire extinguishers should be checked often for proper location, seals, markings, and inspection tags. The areas around the extinguishers should be clear. The fire extinguisher location should be marked with a target arrow or with diagonal red and white stripes visible from any direction within the shop. Fire extinguishers are checked each month by the fire department; however, during your inspection, check to see that the inspection tag has been properly signed by the fire department inspector and dated so that you can tell when the next inspection is due. Check the seals on your fire extinguishers; when one is found broken, send the extinguisher to the fire extinguisher shop for an inspection or for recharging.

13-15. Fire exits should be clearly marked and kept clear at all times. The supervisor has the responsibility for inspecting the shop to see that the exits are clear; however, everyone else is also responsible for seeing that these same exits are kept clear. All personnel in the shop should know where the exits are, and a building evacuation plan should be located conspicuously within the shop so

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that all personnel know the proper routes for evacuation.

13-16. *Job site.* An inspection of the job site is just as important as a shop inspection. Many of the items to be inspected are the same as those in the shop. Some of these items are:

- Restrictions
- Floors
- Ventilation
- Building evacuation
- Fire extinguishers

13-17. For example, restrictions cover several areas, such as no smoking, isolated, and security areas. Personnel assigned to the job should comply with any restrictions imposed on the job to prevent injury to themselves and their fellow workers, damage to the building or equipment and any violations of security. For example, your crew is working in a hangar and there are aircraft present. Since aircraft contain highly combustible fuel, you will be required to use a controlled smoking area.

13-18. The crew leader should check the surrounding area before a job is started to determine the restrictions his crew will have to work under, if any. Once he has identified the restrictions, he should bring them to the attention of his workers. As the job progresses, the supervisor should continue his inspection to insure that all personnel are continuing to observe all restrictions.

13-19. The supervisor also checks the floors to see that they are clear of any combustible materials, scrap metal, and furniture that might be in the way or that could be damaged. Combustible materials are especially hazardous when a welder is cutting metal with a cutting torch or using an arc welder. Scrap metal is hazardous to workers because of the possibility of tripping or of being cut. Scrap metal also presents a hazardous condition to the placement of ladders. The main thing to remember when you are inspecting a job site is to make sure that the work area is safe for the workers and other personnel.

13-20. Ventilation is important when personnel are working in close areas. The fumes from soldering acids and cements can be harmful if the building is not ventilated properly. Welding can cause smoke or harmful fumes when certain metals are welded. Again, adequate ventilation is very important. Proper ventilation prevents gas vapors from accumulating in the building. The supervisor should check to see that adequate ventilation is provided for his workers; however, the working leader and individual workers also have this responsibility. Any indication of poor ventilation should be reported immediately.

13-21. All crews should be informed of building evacuation procedures. It is the responsibility of the crew leader to insure that each member of his crew has a way out of the building if the need arises. He should inform his crew of the building evacuation plan and the evacuation locations. It is the supervisor's responsibility to inspect *all* job sites to insure that this is done. For example, if the supervisor asks the crew leader what the building evacuation plan is and what the evacuation routes are, he should be able to answer without hesitation.

13-22. Fire extinguishers are especially important at a job site when you are working with open flames. When welding or cutting operations are being performed, the welder should have a fire extinguisher readily available. There are some operations that require that an individual stand by with a fire extinguisher; this is called a fire watch. It is extremely important that *all* personnel on the job site know the location of *all* fire extinguishers required by the job in the event the need arises for their use. It is your responsibility on any job to see that adequate fire extinguishers are readily available and that the seals are not broken.

13-23. As you can see, there are many things to look for when you are inspecting your shop or job site other than just quality workmanship. It takes time to learn these things; however, there is no reason why you cannot make yourself an inspection check list of all your required inspection items. This check list should prove to be very useful and should insure that you do not overlook even the smallest item. After you gain experience you will find yourself making inspections in the shop and on the job without even realizing it.

13-24. **Equipment.** Equipment can be broken down into three categories: stationary, portable, and handtools (tool kits). Equipment should be inspected by the supervisor to make sure it is in good working condition and safe for use. Stationary and portable equipment are inspected monthly; however, tool kits do not require an inspection that often, because restrictions on their use are not as critical.

13-25. *Stationary.* There are several inspection items for stationary equipment, such as those shown in figure 37. The first item is cleanliness. Check the paint for grease spots, dirt, and any other foreign substance. Check the unpainted area for rust and grimy oil or grease; be sure the rolls are lightly oiled to prevent rust. Check your stationary equipment to see that only the authorized colors of paint are used—orange for extremely hazardous areas, ivory for less hazardous areas, and machine gray for any other painted area. The remaining inspection items on the check list were discussed in Volume 2 of this course.

13-26. To refresh your memory a little, let's discuss an inspection of the power slip roll forming machine to see what is done. This machine is shown in figure 38. First you make a visual check

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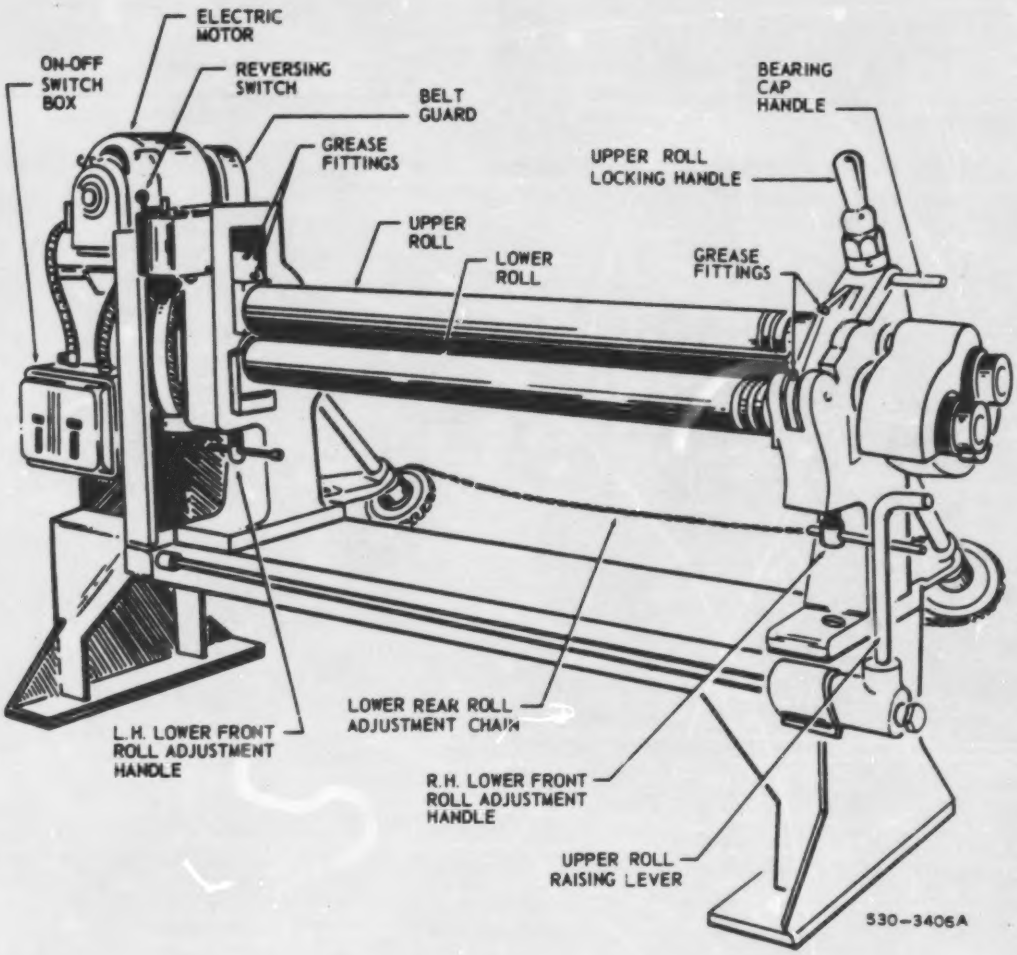
ELECTRIC MOTOR
ON-OFF SWITCH BOX
REVERSING SWITCH
BELT GUARD
GREASE FITTINGS
UPPER ROLL
LOWER ROLL
BEARING CAP HANDLE
UPPER ROLL LOCKING HANDLE
GREASE FITTINGS
LOWER REAR ROLL ADJUSTMENT CHAIN
L.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
R.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
UPPER ROLL RAISING LEVER
530-3406A

Figure 38. Power-operated slip roll forming machine.

of the painted and unpainted surfaces. Next, check to see that ivory paint has been used to identify any hazardous work areas on the machine, such as the upper roll locking handle, the upper roll raising lever, and the moving parts at each end of the rolls. Check to see that orange paint has been used to identify the extremely hazardous areas of the lower roll adjustment chain gears on each end of the shaft. These areas are designated as extremely hazardous because of the movable open gears. Now check to see if the machine needs lubrication or has been overly lubricated. This is done in conjunction with checking to see when the last lubrication was performed and what maintenance, if any, was performed. Check the condition of the rolls for such things as misuse, pits, and creases.

13-27. Most machines are hazardous, and this one is no exception. A warning sign is posted near the machine to warn personnel of all operational dangers. Check to insure that this sign is present and current. Check the operating switch to see that it is working properly, and check the electrical cord for breaks or cuts that could expose the wiring. Check the belt guard to see that the supporting bolts are secure and the guard is properly positioned. Now, operate the machine to determine its present condition and to see if any maintenance is needed.

13-28. Our next example of an inspection is a stationary unishear, such as the one shown in figure 39. Again we start with cleanliness of the machine, then check to insure that the hazardous work areas are properly identified. On this machine, the ivory markings are different from those on the power slip roll forming machine in that the throat and the area around the cutting blades are painted ivory. Check the lubrication points or grease cups for lubrication. Check the maintenance forms to see what maintenance has been performed and when the next maintenance check

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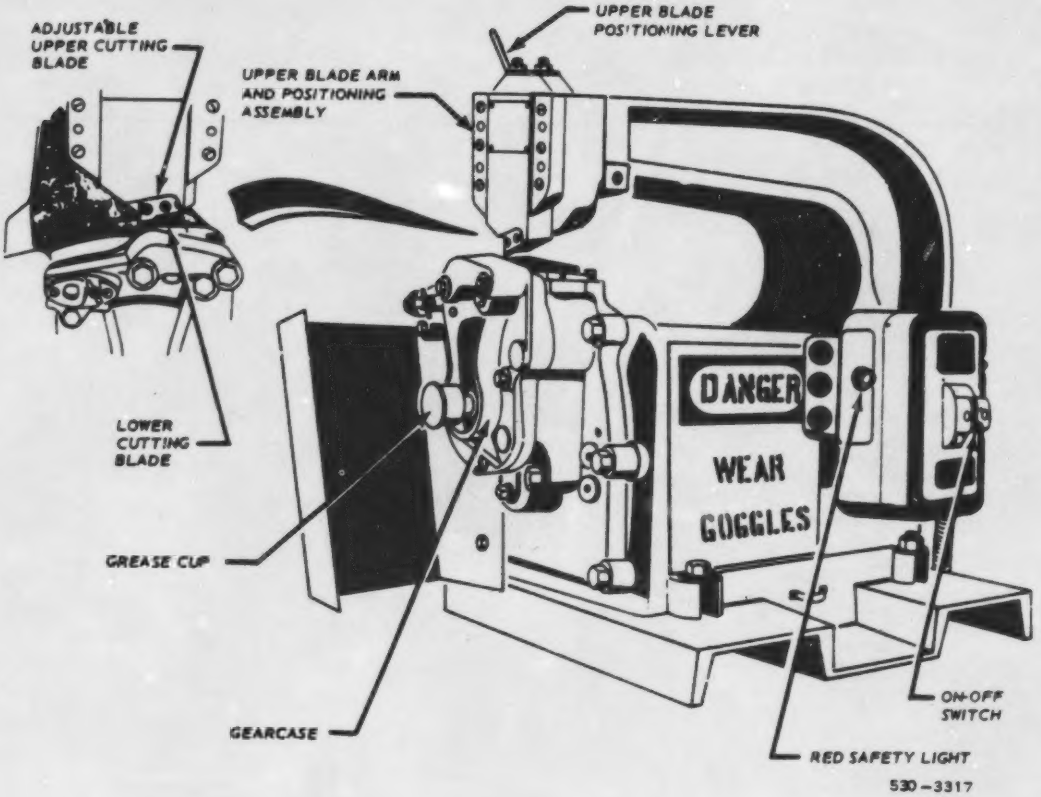
ADJUSTABLE UPPER CUTTING BLADE
UPPER BLADE POSITIONING LEVER
UPPER BLADE ARM AND POSITIONING ASSEMBLY
DANGER
WEAR GOGGLES
LOWER CUTTING BLADE
GREASE CUP
GEARCASE
ON-OFF SWITCH
RED SAFETY LIGHT
530-3317

Figure 39. Stationary unishears.

is due. Check the cutting blades for proper clearance and condition. Note that this machine has a warning sign to warn personnel that eye protection is required when operating the machine. Check the operating switch, electrical cord, and warning light to insure that they are in good condition. Now check the overall condition of the machine by operating it.

13-29. Let's inspect one more piece of stationary equipment for the different markings and service requirements. For example, inspect a bench grinder of the type shown in figure 40. Here again, there are several items and areas to be checked. First, check the machine for cleanliness and proper identification of any hazardous areas. The wheel guard, face guard, and work rest are painted ivory to identify them as hazardous work areas. (The top of the work rest is not painted.) Most bench grinders have permanently lubricated bearings; but since some do not, you will need to check your particular machine for lubrication. Check the maintenance form to see if any maintenance has been performed. Pay particular attention to the grinding wheels, making sure to check each grinding wheel for cracks, chips, wear, and loose mounting nuts. Check to see that this machine has a warning sign indicating that eyes must be protected when one is operating the machine. Make sure that a pair of eye goggles or a face shield is located near the machine and that each is in good condition. Check the operating switch and electrical cord for proper operation and serviceability. Next we come to the guards and work rest. Check to insure that the wheel guards cover two-thirds of the grinding wheels. Also check to see that the work rest is adjusted so that it does not touch the grinding wheels and that there is no more than a one-eighth-inch clearance between the work rest and the grinding wheels. Now, operate the grinder and check for any vibration which may indicate loose mounting bolts, worn bearings or shaft, or a bent shaft.

13-30. *Portable*. Portable equipment inspections will include a check on the safety and condition of the equipment. For example, electrically powered unishears, hand drills, grinders, and sanders are checked to insure that all electrical cords are free from breaks, that they have the proper ground connections, and that all switches operate properly. The cutting blades on unishears should be checked for sharpness and wear. The portable hand drill chucks should be checked to see that

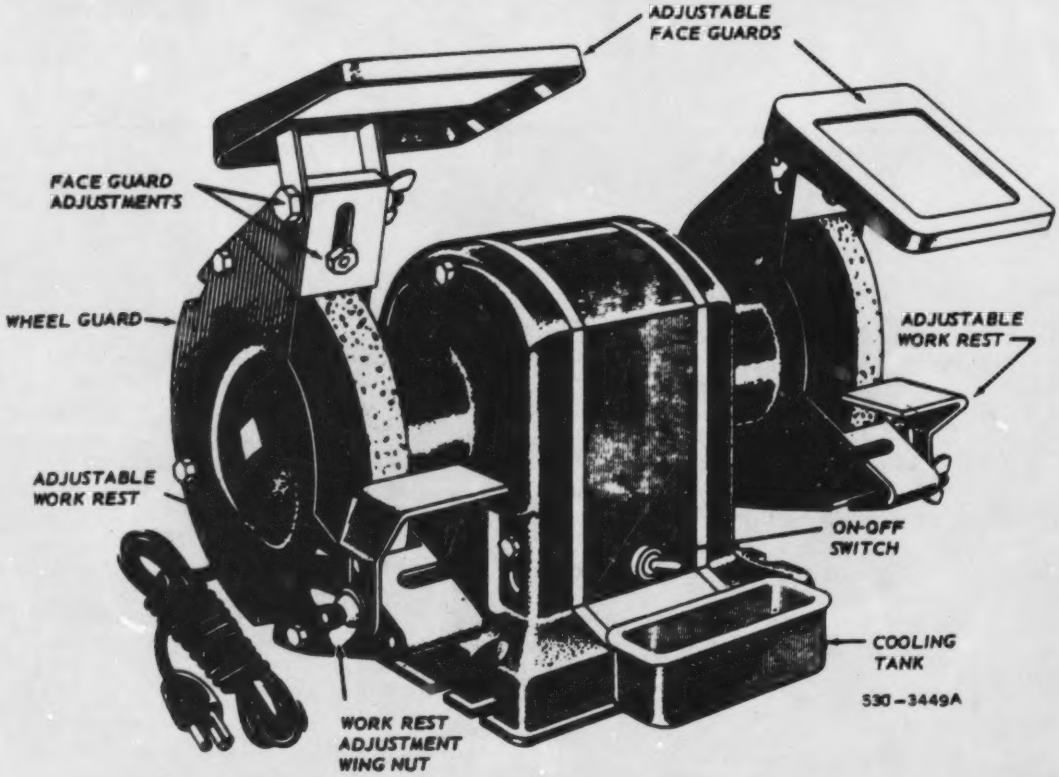

Figure 40. Bench grinder.

they operate properly. Grinders are inspected to insure that the guard provides adequate protection for the operator. After performing these inspections, operate the electrically powered portable equipment to check the brushes for arcing and excessive wear.

13-31. Fire pots and blowtorches are checked for cleanliness, leaks, and defective shutoff valves and pumps. The shutoff valve should turn the gas off completely when the fire pot or blowtorch is not in use. The pump should be in good condition and should not allow air to escape. The "fill" cap should not allow any fuel to leak. Fire pot and blowtorch storage areas are checked to insure that there is adequate ventilation so that gas vapors can escape.

13-32. Aluminum and wooden ladders used to accomplish your work are also inspected to insure that they are always in good condition and ready for use. Since portable wooden ladders are not painted, you can easily see any small cracks or breaks in the wood. Aluminum and wooden ladders, including step and extension ladders, are checked for broken rungs (steps) and for general serviceability. *All* ladders are supposed to be equipped with shoes to prevent the ladder from slipping while in use. Extension ladders have swivel shoes that remain parallel to the surface on which you place the ladder. These swivel shoes are checked to see that they do in fact swivel with no evidence of binding.

13-33. *Handtools.* Inspection of handtools involves checking the condition and serviceability of those tool kit items charged to an individual. A monthly or quarterly inspection is usually sufficient; however, it is your responsibility to keep all tools assigned to you in good working condition. Many of the tool checks are the same as those we studied earlier in this course.

13-34. Inspect hand snips or shears for dull cutting blades, loose hinge bolts, damaged blades, and corrosion. These conditions usually result from misuse. Check hammers and mallets for broken handles and loose wedges; also check for rough faces on the hammer heads. Chisels are checked for mushroomed striking heads, dull cutting edges, and soft cutting edges. Center and prick punches are inspected for dull points, point angles, soft points, and mushroomed striking heads. Inspect rivet sets for mushroomed striking heads, worn setting slots and worn heading cups. Check all screwdriver blades and handles for cracks and breaks.

13-35. **Personnel.** Inspection of personnel in the sheet metal and welding shop is somewhat different from other types of personnel inspections. In the shop you are looking for conditions that may cause injuries, such as wearing jewelry and loose clothing when operating machinery.

13-36. You should be observant at all times for the "joker" in the shop. He's the one who thinks anything he does is funny and that any prank he pulls is all right no matter how it affects someone else. In a sheet metal shop this situation cannot be tolerated, because the "joker" will eventually hurt himself or someone else.

13-37. The "joker" is not the only person you should observe when making an inspection. What about the man who is operating a grinder without eye protection or guards; or the worker who is using the side of a grinding wheel? He may not hurt as many people as the "joker," but he can surely hurt himself. What about a man who wears loose clothing when operating a power slip roll, or the one who wears a ring or a loose identification bracelet when working on or operating machines? Any of these items might be caught by the machine, with the possibility that a finger, hand, or arm may be pulled into the cutting blades or other moving parts.

13-38. In the welding shop, you should see that all welders and their helpers are using protective clothing such as leather gloves and sleeves. Eye protection in the welding shop is a "must," since light rays produced during welding are extremely hazardous. Flying particles of metal are also hazardous during welding operations. Helmets used for arc welding should have shaded lenses—a number 6 for settings up to 30 amperes, a number 8 from 30 to 70 amperes, and a number 10 for 70 to 190 amperes.

13-39. **Supplies.** Supplies, such as materials for your work orders, bench stock, and one-time orders, should be kept separate and under control. Some of the supplies must be stored in a particular manner and in a designated storage area. For example, oxygen and acetylene bottles normally should be stored in an upright position. Oxygen bottles may be stored in a horizontal position for short periods, but acetylene bottles must be stored upright. Gasoline must be stored in a safe, well-ventilated area and in an approved container. Other supplies are stored in bins that are marked to identify the contents. Now let's see how you accomplish an inspection of supplies.

13-40. *Use and control of supplies.* Make sure that supplies are kept separate and that they are used as intended. For instance, work order materials should be kept separate from your bench stock and one-time issue supplies. Marking work order materials with the work order numbers for which they are intended identifies the materials with the correct job.

13-41. In the preceding chapter of this text you studied the use of AF Form 333, Materials and Supplies Used. From this study you will recall some of the ways of controlling the use of supplies. When materials or supplies are used from another work order or from bench stock, a Form 333 is used to transfer the materials to the receiving work order. This method helps you to account for additional supplies and helps to determine a more accurate cost for the work order.

13-42. Another method of controlling supplies is to screen the DD Form 1150, Request for Issue or Turn-In. The inspection for one-time issue items includes the screening for items that could be substituted from bench stock. The quantity requested is checked to prevent overordering of items. If the request is for two boxes of screws and you only need one box, the quantity should be reduced. It is not good practice to order more supplies than you need just to have them on hand. When you accomplish an inspection on the use and control of supplies, all you are actually doing is inspecting to see that good management is being used.

13-43. *Storage of supplies.* You have probably noticed that bins usually consist of boxes sitting on shelves in the bench stock storage area. Each box is identified with a yellow status tag, which includes the item description, stock number, and document number. The last four digits of the document number are the location numbers for the box (bin). Items should be properly labeled and stored in the correct location. Items should not be mixed. For instance, you do not want ¼-inch stove bolts mixed with $^{3}/_{16}$-inch stove bolts. Each item has a stock number, and that item is supposed to be stored in the bin that lists that stock number.

13-44. During your inspection of bench stock items, check to see that the item description fits the item stored in the box and that the box is stored in the proper location. Also check for items that are exhausted, so that an out-of-cycle issue can be requested.

13-45. Remember, we said that some supplies, such as acetylene and oxygen bottles, must be stored a certain way and in a certain place. Acetylene bottles are short, round metal containers painted yellow, and oxygen bottles are tall, round metal containers painted green. When these containers are stored, they are kept separate from one another by partitions. The empty bottles and full bottles are kept separated: the empties are marked (MT) so that the full and empties are identified. They are secured by chains placed around the bottles and fastened to the wall to keep the bottles from being tipped over. Both oxygen and acetylene bottles have a valve on which a regulator is fastened. A metal cover that screws onto the cylinder should be kept on the bottles at all times, because it protects the valve.

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13-46. Acetylene and oxygen bottles may be stored inside a well-ventilated building. If stored outside, they should be kept away from extreme heat (exceeding 125° F.). Since ice and snow can cause corrosion, keep the bottles cleaned off as necessary.

13-47. Sheet metals, such as galvanized steel, stainless steel, and aluminum, are usually stored in an upright position. The surface of metal sheets such as copper, stainless steel, and aluminum should be protected to prevent scratches; this is usually done by placing cardboard between the sheets. You learned this in an earlier volume of this CDC when you studied about the care of metals. The bins should be clearly marked to identify the metal, and each bin should exhibit a stock number. If the metal is on bench stock, it should have a document number on the tag.

13-48. This completes our discussion about inspections of work orders, work areas, equipment, personnel, and supply. Next, let's discuss what to do when you find something wrong during one of the inspections. Have you ever wondered why inspections are performed, or what to do if you find something wrong during an inspection? This is discussed in the next section.

14. Interpretation of Inspection Findings and Recommendations for Corrective Action

14-1. We should point out that you usually inspect and interpret the findings at the same time. However, to make the text easier to understand, we have separated the two topics. Corrective action follows the interpretation. Now let's explore some examples of interpretation of inspection findings and the corrective action taken.

14-2. **Work Areas.** Suppose that during an inspection you find oily rags mixed with clean rags. You learned from Section 13 that oily rags should not be stored with clean rags and that separately marked containers with lids should be used; therefore, you know there is a violation of safety directives which must be corrected.

14-3. You must interpret the inspection findings before corrective action can be made. For instance, think about the containers for the rags. In the first place, are the containers properly marked? If they aren't, the discrepancy is not necessarily due to carelessness or neglect. If the containers are properly marked, then you could consider that the violation of mixing oily rags with clean rags was the result of carelessness.

14-4. Let's think about what we can do if the containers are properly marked. You can caution all the workmen to make sure they use the proper storage for oily and clean rags. After this is done, followup inspections and close observation of the containers should reveal the offender and prevent recurrence of the violation.

14-5. Now let's look at the other side of the situation. Suppose the containers are not properly marked. This means that you, the supervisor, are at fault as much as the person who put the oily rags in the container with the clean rags. You can correct the violation by marking the containers properly and instructing the workers in the use of storage containers.

14-6. **Equipment.** Equipment inspection can reveal many discrepancies, since there are many items to inspect. Suppose that during the inspection of a bench grinder you find one of the wheels with a small crack. This situation will require a decision as to whether the crack can be dressed out or whether the wheel should be replaced. If a closer examination reveals that the length of the crack is from the grinding face of the wheel to the arbor hole for the shaft, it cannot be dressed out. This would create a hazardous condition for the operators, and your decision (recommendation) should be to replace the defective wheel with a new one.

14-7. Now that you have evaluated the findings and made a recommendation to correct the discrepancy, a new wheel is installed. A spare wheel should be available in the shop; however, if there is not one available, order a replacement. This is done by initiating a DD Form 1150, as you learned earlier in this text. In this case, it is advisable to order two wheels, so that one will be available for standby.

14-8. When a replacement wheel is not available, the grinder should not be used. With the power supply turned off, the old wheel should be removed, and a sign should be placed on the grinder prohibiting operators from using the grinder. The reason the grinder should not be operated with one wheel is that the machine will be out of balance and will vibrate. Thus it is a good idea to have a spare wheel on hand so that the grinder will not have to be put out of operation while a new wheel is being obtained.

14-9. In another example, a ¼-inch portable electric hand drill does not operate. Your evaluation of the trouble indicates that the motor is burned out and that the gears are worn. As a result of your evaluation, the drill should be condemned. To confirm this you should have the electric shop check the motor, switch, and power cord. After this is done, the gears should be checked to see if they are worn or have broken teeth.

14-10. Suppose your evaluation is correct, and the drill motor is burned out and the gears are defective. Since the cost to repair the drill is excessive, a replacement should be made. First, the condemned drill should be tagged with a DD Form 1577, Rejected, Condemned, and UR Tag. Initiate this red tag by filling in the necessary information. The tag should be attached to the defective drill and signed by a supply inspector. Next, AF Form 601b is initiated by the supervisor to turn in the condemned drill and request a replacement. This is done by filling in the required information on the 601b, as indicated earlier in this volume.

14-11. **Supplies.** Suppose the inspection of supplies reveals that bench stock and work order materials are mixed. You should evaluate the discrepancy and determine the cause before a recommendation is made to base supply. Let's use the information you learned from Section 13 to do this. Remember that bench stock and work order materials should be kept separated.

14-12. First of all, determine if there is proper storage for work order and bench stock materials. Next, determine if the work order materials are properly marked and if the bench stock storage bins are properly marked. Now that this is done, you should find out if all personnel are properly trained in the procedures for storing supplies in the shop.

14-13. If a discrepancy is due to inadequate storage it can be corrected by making a specific location for work order and bench stock materials. If the cause is due to personnel not knowing the procedures for storing supplies, a training program should be initiated to instruct all personnel in storage procedures.

MODIFICATIONS

Chapter 6, pages 79-93 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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WORKBOOK

Supervision and Management

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Volume Review Exercise

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STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume. Use the Guide for review before you take the closed-book Course Examination.

2. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the items missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Numbers 400 through 416

Guide Numbers	
400	Supervisory Responsibilities and Personnel Management; Duties and Responsibilities; pages 1-5
401	Promoting Harmonious Relationships and Resolving Personnel Problems; pages 5-11
402	Supervising Shop Personnel; pages 11-18
403	Supervision of Sheet Metal Fabrication and Repair Operations; Checking Accuracy of Pattern Development; pages 19-25
404	Checking Sheet Metal Fabrication; pages 25-34
405	Checking Fabricated and Repaired Items for Accuracy and Quality; pages 34-35
406	Determining Job Requirements; Inspecting Sheet Metal Parts for Damage or Deterioration; pages 36-44
407	Determining Limitations and Methods of Repair; pages 44-46
408	Planning and Scheduling Work; Workload Assignments and Schedules; pages 47-57
409	Performance Control Program; pages 57-59
410	Man-Hour Utilization; pages 59-60
411	Equipment and Supplies; pages 60-68
412	Inspections and Evaulations; Inspection Procedures; pages 69-77
413	Interpretation of Inspection Findings and Recommendations for Corrective Action; pages 77-78
414	On-the-Job Training; The Role of On-the-Job Training; pages 79-84
415	Duties and Responsibilities for OJT; pages 84-85
416	Conducting On-the-Job Training; pages 86-93

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading. Complete all chapter review exercises.

CHAPTER 1

Section 1

Objectives: Given supervisory metalworking situations, to be able to answer questions about 5-, 7-, and 9-level supervisory responsibilities and chain of command.

1. Which contains the most detailed information about the duties and responsibilities of a 5-level sheet metal specialist–AFM 39-1 or STS 53132/52/72? (1-3)

2. As a 5-level sheet metal specialist, what will be your supervisory title if you are in charge of two apprentice sheet metalworkers and are repairing the gutters on a building? (1-5)

3. If a 5-level sheet metal specialist is unable to solve a pattern layout problem, whom should he ask for help? (1-16, 19)

4. A 5-level sheet metalworker is leader of a crew installing a hood over a range in a dining hall. At the same time, the sheet metal supervisor and superintendent will also be performing some supervisory duties related to the hood installation.
   a. Which 3 of the 8 supervisory duties listed in paragraph 1-16 of the text will the sheet metal supervisor most likely perform in connection with the hood installation? (1-16)

   b. Which 2 of the 16 supervisory duties listed in paragraph 1-22 of the text will the superintendent most likely perform in connection with the hood installation? (1-22)

Section 2

Objectives: Given personnel management situations, to be able to list personality traits of leaders; solve problems concerning basic human needs and techniques of good human relations, follow through a problem-solving procedure, and answer questions about individual differences and resolving personnel problems.

1*a.* What are the 10 personality traits of a leader that are listed in this text? (2-2)

1*b*. What are five additional personality traits which you have observed in supervisors that can be added to the list? (2-1, 2)

2. In the following situation, what basic human need was the supervisor overlooking that caused Airman Abbott to lose interest? Airman Abbott had completed his 5-level OJT in the sheet metal shop. He was a conscientious worker and had a great deal of pride in his work. He could do a good job of teaching the new trainees how to operate the shop machines and how to use tools properly. The supervisor often assigned him these duties. However, the supervisor usually picked Airman Baker to be a crew leader and to assist with shop paperwork. The supervisor frequently congratulated Baker on how well he worked with men and did his job. The supervisor had a dislike for training, and seldom congratulated Abbott. After several months Airman Abbott became disinterested and the quality of his work deteriorated. (2-4)

3. Individuals differ mentally, emotionally, physically, and socially. Which one of these differences should be considered when selecting a worker to perform a job that requires a considerable amount of heavy lifting? (2-11–14)

4. In the following situation, what was apparently wrong? Airman Cain did a good job in the sheet metal shop, but he was a shy boy; he had only a "good morning" or a nod for his supervisor. Since Airman Cain was doing his job well, the supervisor left him alone and never told him how he was getting along. After several months, Airman Cain became restless and was frequently absent. His attendance record became poor for seemingly minor reasons, and his production fell off. The supervisor talked to him about his absences. (2-17)

5. Airman Day frequently gets injured while on the job and in the sheet metal shop. As a supervisor you must decide what to do to solve the problem. Answer the following questions concerning the handling of Airman Day's problem.

   a. Which step in problem-solving techniques will help you to define Airman Day's problem? (2-26, 27)

   b. Which of the steps in problem-solving techniques did you use to find out that Airman Day had a history of continuous accidents before entering the Air Force? (2-28)

   c. Which step are you using if Airman Day is assigned additional training in safe operation of machines? (2-32)

6. When discussing a problem with a complaining worker, what is one of the most important things a supervisor can do to get the facts and at the same time reduce the dissatisfaction of the worker? (2-41, 42)

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Section 3

Objectives: Given supervisory situations, to be able to determine sequence for orienting new workers, identify types of work directives, identify different types of requirements items and performance items, answer questions about evaluation of personnel, and answer questions about scheduling leave.

1. Correctly sequence the selections listed below in the order in which they should be performed when orienting a newly assigned worker:

   a. Discuss the shop and his new job.
   b. Introduce him to other personnel.
   c. Discuss personal topics such as his experience and his family.
   d. Turn him over to the person who will be directly responsible for his training.
   (3-4–6)

2. What type of direction is inferred in each of the four examples listed below?

   a. "George, would you repair that hole with a flat lap seam patch?"
   b. "It would be helpful to remove the canopy before we repair it."
   c. "John, make a replacement for this downspout shoe, and install it immediately."
   d. "It is necessary that we complete this job today. Who is willing to work late to get the job finished on time?
   (3-13, 14)

3. How can the sheet metal supervisor free himself from some of the paperwork duties of the shop office? (3-23)

4. Use the requirements column of figure 1 (in the text) and answer the following questions concerning task 1a "Straight joints of round pipe:"

   a. What is the acceptable time per joint?

   b. What is the acceptable quality of results in terms of how well the job must be performed?

   c. What is the acceptable manner of performance?
   (3-26; Fig. 1)

5. Use the performance column of figure 2 (in the text) and answer the following questions concerning the tasks.
   a. Was the time required to fabricate the straight joints of round pipe acceptable, above average, or below average?

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b. Was the quality acceptable for the completed double wall thimble?

c. Was the manner of performance (supervision received) for the storm collar acceptable, above average, or below average?
(3-34; Fig. 2)

6. If a supervisor lets his friendship influence the rating he gives a subordinate, is the rating objective or subjective? (3-36)

7. What Air Force form should you use if your supervisor asks you to write a letter concerning how well an airman (whom you have trained) can fabricate and install duct work? (3-38)

8. In addition to enabling the supervisor to make maximum use of shop personnel and time, what is another advantage to having a leave schedule for the shop? (3-44)

CHAPTER 2

Section 4

Objectives: Given sheet metal pattern data, to be able to check pattern development for mistakes, determine cause of mistakes, and determine what will result if mistakes are not corrected.

1. CRE figure 1 includes a pictorial view, plan view, elevation view, true length chart, and half pattern for a transition. The transition is supposed to be 24" x 36" at the base, 24" long (high), and have a 20" diameter top opening that has a center which is offset 6" from the center of the rectangular base. Assume that you are checking this pattern development for a trainee. What are the two mistakes in the plan view that caused the pattern to be short on side AD, and the top be too small? (4-6; CRE Fig. 1; and Vol. 1 of this course)

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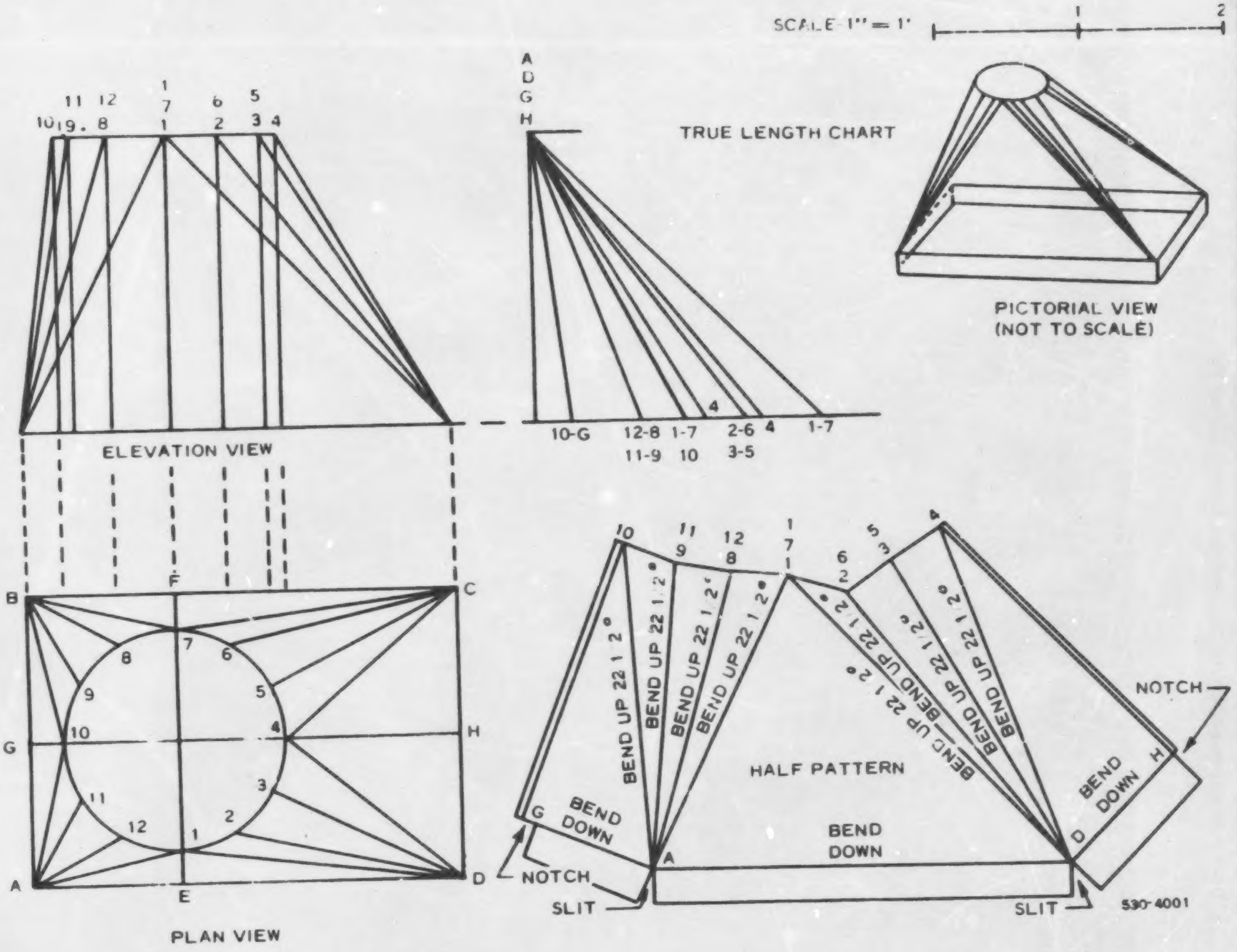
SCALE 1" = 1'
1
2
TRUE LENGTH CHART
A
D
G
H
PICTORIAL VIEW
(NOT TO SCALE)
11 12 1 6 5
10 9. 8 7 1 2 3 4
ELEVATION VIEW
10-G
12-8
11-9
1-7
10
2-6
3-5
4
4
1-7
B
F
C
G
H
A
E
D
1 2 3 4 5 6 7 8 9 10 11 12
PLAN VIEW
10
11
9
12
8
1
7
1
6
2
5
3
4
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
BEND UP 22 1/2°
HALF PATTERN
BEND DOWN
BEND DOWN
BEND DOWN
G
A
D
H
NOTCH
NOTCH
SLIT
SLIT
530-4001

RE Figure 1. Development of transition pattern (errors included).

2. Suppose you are checking the pattern shown in CRE figure 1 for additions and seam allowances. The base is to be set over and cover a frame that is 4 inches high. Will the addition to the base (as shown on the pattern in CRE fig. 1 be of correct height? (4-9; CRE Fig. 1: and Vol. 1 of this course)

3. Figure 7 (in the text) shows the additions and seam allowances to patterns for a shower stall. You are supervising a trainee who has developed the patterns. What changes must he make to the patterns if the Pittsburg lock forming machine is out order and the cornice brake has to be used to make the seams? (4-11: Text Fig. 7: CRE Fig. 2; and Vol. 3 of this course)

Type of Seam	Size of Seam (Width = W) (Height = H)	Gage of Metal and Decimal Equivalent	Material Required		
			Formula (Thickness = T)	Side 1 or Piece 1	Side 2 or Piece 2
Standing	1" H 1" H	24 (0.025") 18 (0.050")	3H + 2T 3H + 2T	1" 1"	2 1/16" 2 1/8"
Grooved	1/2" W 1/2" W	24 (0.025") 20 (0.037")	3W + 5T 3W + 5T	1/2" 1/2"	1 1/8" 1 3/16"
Corner Double	1/4" W 3/8" W	24 (0.025") 20 (0.037")	3W + 2T 3W + 2T	1/4" 3/8"	9/16" 7/8"
Bottom Double	1/4" W	24 (0.025")	3W + 2T	1/4"	9/16"
Pittsburg Lock Made With Pittsburg Machine	———	24 (0.025")	Determined by Model of Machine	1/4" or 5/16"	1" or 1 1/16"
Pittsburg Lock Made With Cornice Brake	1/2" W	24 (0.025")	2W + 1/4" + 1/4"	1/4"	1 1/4"
Dovetail	1/2" H & 1/2" W	26 (0.018")	———	1/2"	———

530-3910

CRE Figure 2. Seam allowances for lock seams.

4. You are checking the pattern in CRE figure 1 for correct notching. Is the notch near point G incorrect or is the notch near point H incorrect? What is wrong? (4-12; CRE Fig. 1; and Vol. 3 of this course)

5. You are checking the bending instructions for the transition pattern in CRE figure 1. What mistakes do you find? (4-13, 14; CRE Fig. 1; and Vol. 3 of this course)

Section 5

Objectives: Given data about sheet metal layouts, cutting operations, drilling and punching operations, folding and forming operations, and seaming operations, answer questions, to be able to see that proper tools and equipment are used correctly, to check patterns for correct allowances and bending instructions, that items have been fabricated according to the patterns, and to determine if mistakes have been made.

1. You have assigned to a trainee a cutting operation that involves straight cut 45° miter notches across two corners on 100 pieces of 24-gage metal. The trainee decides to cut the corners with straight snips. What bench shears would you suggest he use to improve the cutting operation and save time? Why? (5-4; and Vol. 2 of this course)

2. You are checking a piece of sheet metal that has been cut by a trainee who used the manually operated squaring shears. The back gage and holddown handles were used. The metal is supposed to cut 15 inches wide, but when measured it is 15 inches wide at one end and 15 1/16 inches wide at the other. What is the probable cause of the error? (5-6; and Vol. 2 of this course)

3. You are checking a trainee as he cuts 28-gage metal with hand-operated circle shears. What is wrong if the metal is not cut all the way through during one revolution of the metal? (5-8; and Vol. 2 of this course)

4. An airman you are supervising is using portable unishears to cut out patterns. During the cutting process, the unishears are vibrating excessively and making a rough cut. What mistake is he making in the use of the unishears? (5-9; and Vol. 2 of this course)

5. A trainee under your supervision is cutting a piece of angle iron on the power hacksaw. The metal has slipped and caused the blade to break. What mistake was made? (5-10; and Vol. 2 of this course)

6. A trainee, who is under your close supervision, is learning to operate a drill press. If the hole he drills is too small, which step of the drilling operation did you fail to check? (5-11, 12)

7. You are supervising the fabrication of a shower stall such as shown in figures 7 and 8 (in the text). The rivet holes in the sides, back, top front, and center front are being punched with the rotary punch by a trainee. He is having trouble because of the size of the back and side pieces. What hand-held punch should you recommend that he use to improve the situation? (5-14; Figs. 7, 8; and Vol. 2 of this course)

8. You are supervising a trainee who is using a cornice brake to make the bends shown on the patterns in figure 7 (in the text).

   a. What are three things that you should check the folded pieces for? (5-19; Fig. 7; and Vols. 2 and 3 of this course)

   b. What are two safety procedures the trainee should observe when using the cornice brake? (5-19; and Vol. 2 of this course)

9. You are supervising the fabrication of takeoff joint 12 in figure 11 (in the text). A check of the ¼-inch flange for the Pittsburg lock seam on the pieces made from pattern A reveals that the rotary burring machine is cutting the metal along the 90° bends. What mistake is the operator making? (5-24; and Vols. 2 and 3 of this course)

10. What are two checks a supervisor should make to reduce the chances of a trainee damaging a slip roll forming machine? (5-25; and Vol. 2 of this course)

11. A trainee has made the pockets for a grooved seam for a joint of round duct. What is wrong if the pockets are on the same side of the metal and will not lock together? (5-28; and Vol. 3 of this course)

12. A trainee is making a joint of rectangular duct that will be assembled with *one* Pittsburg lock seam. What should you tell him if he asks which side of the sheet the ¼ -inch flange should be on? Why? (5-29; and Vol. 3 of this course)

13. You are checking a trainee's patterns for correct seam allowances:

    a. What side tabs are required for a dovetail seam to be made on a 26-gage round duct joint? (5-31; CRE Fig. 2; and Vol. 3 of this course)

    b. What is the allowance requirement for a 1-inch standing seam to be made across a 24-gage rectangular duct joint? (Remember each side of the metal to be joined has a different allowance for a 1-inch standing seam.) (5-32; CRE Fig. 2; and Vol. 3 of this course)

14. A trainee is learning to install metal roofing with a batten seam such as that shown in step B of figure 12 (in the text). What would be the result if he allows ½ inch too little (on the roofing sheet) for the seam? (5-36; Fig. 12; and Vol. 3 of this course)

Section 6

Objectives: Given data on fabrication and repair of sheet metal items, to be able to answer questions about inspection of such items. Also answer questions about checking and supervising the work of newly assigned trainees.

1. At which point in a duct fabrication (layout, pattern transfer, or cutting operation) should you start checking and supervising a newly assigned trainee? (6-1-5; and Vol. 3 of this course)

2. A trainee has made a 20″ x 30″ filter for the hood shown in figure 14 (in the text). What are the correct dimensions? (6-2; Fig. 14)

3. Takeoff joint 12 in figure 15 (in the text) has been replaced. While you were on another job, a trainee made new drive slips from a pattern that measures 2¼″ X 12″. After you inspect these drive slips, what should you have him do? Why? (6-4; Fig. 15; and Vol. 3 of this course)

4. If a trainee is trying to install a roof jack which has a 6 to 12 pitch, on the roof shown in figure 16 (in the text), will the stack lean toward the peak or away from the peak? (6-5; Fig. 16; and Vol. 1 of this course)

CHAPTER 3

Section 7

Objectives: Given data about damaged or deteriorated sheet metal components, answer questions about inspecting for corrosion, damage, and leaks. Answer questions about removing corrosion. Determine corrective measures when corrosion is found, and determine what kind of metal to use for repairs.

1. When the horizontal blades of a register like the one shown in figure 17 are adjusted to be three-fourths open but one blade completely closes, what damage should you look for? (7-6; Fig. 17)

2. After a bad wind, the storm collar, upper stack, and vent cap of a stack assembly (such as that shown in fig. 16) were replaced. After installation, what items should be inspected to insure that the roof jack does not leak during future rains? (7-8; Fig. 16)

3. After strong winds from the opposite direction of the prevailing wind, what three items of a corrugated roof (like the one shown in fig. 18) should be closely checked for damage? (7-12; Fig. 18)

4. Your inspection of wind damage to a fascia and gravel guard flashing (like the one shown in fig. 19) indicates that the nails have worked loose from the bottom strip. The copper fascia is now held only at the top by the nails in the roof deck. What kind of metal nails should you specify to refasten the bottom strip? (7-16; Fig. 19)

5. Ice buildup has caused a gutter (such as the one shown in fig. 20) to sag in several places. What should you look for when determining what repairs are needed? (7-18--20: Fig 20)

6. You have a work order to repair a damaged gutter which is located over a loading dock. The gutter has been damaged by a loaded truck which backed into the gutter. What parts of the gutter (as shown in fig. 20) should you inspect if it is flattened near one end where a drop outlet is located? (7-20; Fig. 20)

7. The inspection of a water storage tank for an evaporative cooler reveals corrosion in three stages like that shown in views A, B, and C of figure 21. Further inspection reveals that 5 percent of the corrosion is like that in view A, 25 percent like that in view B, and 70 percent like that in view C. Why should the water storage tank be replaced instead of repaired? (7-25, 26; Fig. 21)

8. What should you do when inspecting the exhaust duct system of a plating shop if you find severe corrosion in one of the elbows? (7-28)

9. Galvanized flashing such as that shown in figure 16 extends under the roofing material. How can you detect the early stages of corrosion which have occurred to the hidden surfaces? (7-31; Fig. 16)

Section 8

Objectives: Given data about limitations and methods of repair, to be able to answer questions about type of building construction, location of repair jobs, and method of repair to use. To be able to determine what method of repair to use, if repairs can be made in the shop, if a job can be completed in a specified time, and if available bench stock is sufficient for a job assignment.

1. What type of building construction (permanent, semipermanent, or temporary) would most likely have copper gutters and downspouts? (8-3)

2. Location of a repair job is one of the limiting factors that must be considered when determining the method of repair to use. What are two classes or types into which location of repair jobs can be subdivided? (8-4)

3. A shop-referenced job order is received at 0730 hours for replacement of an entire stack assembly like the one shown in figure 16. The only man available to do the work is the man whose performance rating and fabrication time are shown in figure 2. If materials are available and installation time will require 2 hours, can the stack assembly be fabricated and installed by 1630 hours? (8-8; Figs. 2, 16)

4. The bench stock of 24-gage galvanized sheet metal in your shop includes one sheet 4′ x 10′ and one sheet 3′ x 8′. Can you fabricate the patterns shown in figure 11 without ordering any more metal? (8-9; Fig. 11; and Vol. 3 of this course)

5. An example given in paragraph 8-12 of the text is to repair a damaged register. What repair method should be used if the cost (item 6 in paragraph 8-12) of a new register is one-half of the estimated cost for straightening? (8-5, 12)

6. Assume that the vent cap and upper stack of the stack assembly shown in figure 16 have been found to be severely corroded. It has been determined that both components should be replaced. Can replacement components be fabricated in the shop if material, personnel, and fabrication equipment are available but the cornice brake is out of order? (8-6; 13; Fig. 16; Vol. 3 of this course)

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MODIFICATIONS

Pages 13-14 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 5

Section 13

Objectives: Given problems, to be able to answer questions to reflect an adequate knowledge of the inspection of work orders, work areas, equipment, and supplies for compliance with directives.

1. How can you be sure a work order (AF Form 327) is valid? (13-3)

2. When you are inspecting the work order description and drawing (AF Form 327), what can you do to insure that workmen do not run out of supplies before the job is completed? (13-5, 6)

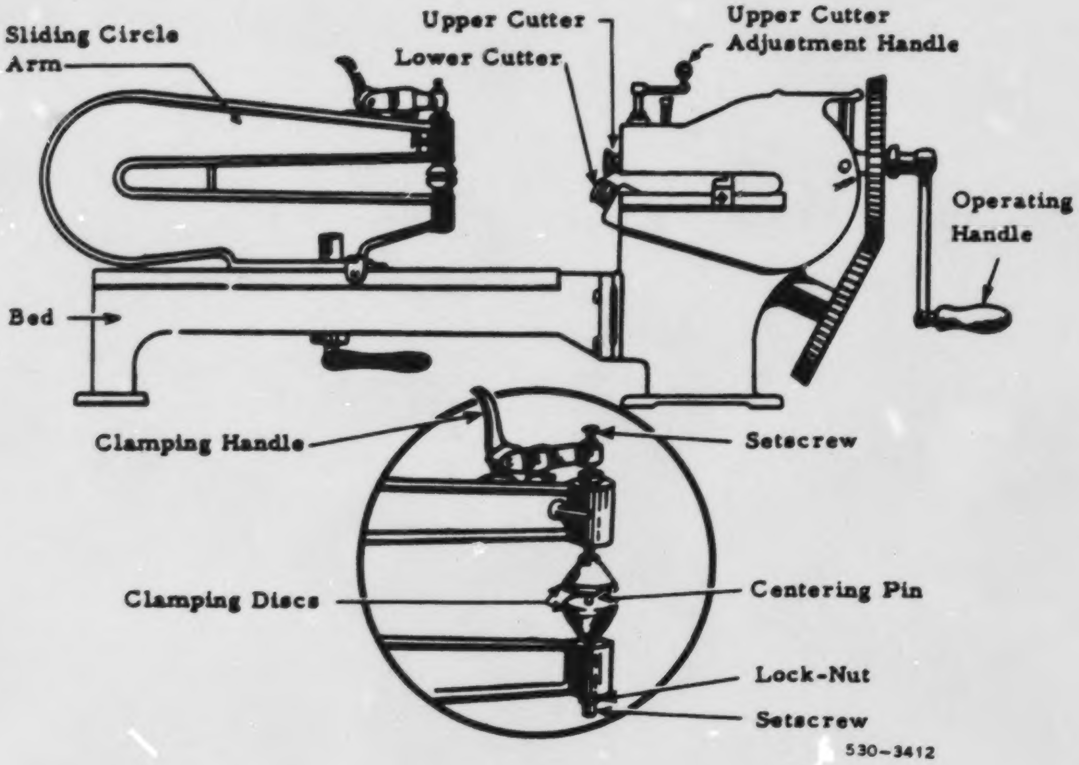
3. What is the probable cause of rust on the unpainted surface of a machine? It has already been determined that moisture is not the cause. Further checks have revealed that machines on the opposite side of the shop do not have rust on the painted surfaces. (13-11)

4. On the fifth day of June you are inspecting the fire extinguishers in the shop and find they were checked on the second day of June. However, the seal is broken on one, indicating that the extinguisher has been used. What should you do? (13-14)

5. What safety warning should you give a crew who will be working around the flammable gases present at the sewage disposal plant? (13-17, 18)

6. What shop discrepancy, if not corrected, could cause personnel to trip and fall? (13-9, 19)

7. In CRE figure 3, the gears that operate the upper and lower cutter blades do not have guards. What color is used to properly identify the gears as a danger area? (13-25, 26; CRE Fig. 3)


Sliding Circle Arm
Upper Cutter
Lower Cutter
Upper Cutter Adjustment Handle
Operating Handle
Bed
Clamping Handle
Setscrew
Clamping Discs
Centering Pin
Lock-Nut
Setscrew
530-3412

CRE Figure 3. Manually operated ring and circle shears.

8. In CRE figure 3, what should you look for during a cleanliness inspection of the painted and unpainted surfaces? (13-25, 26; CRE Fig. 3)

9. Are the wheel guards that are illustrated in figure 40 acceptable from the standpoint of safety? Why? (13-29; Fig. 40)

10. What is included in the personal inspection of a worker who is operating a bench grinder such as the one shown in figure 40? (13-29, 37; Fig. 40)

11. When checking AF Form 327 (work order) and AF Form 1445 (material list) for a job just completed, what did the crew leader fail to do if some materials used from bench stock are not accounted for? (13-41)

12. During an inspection of supplies, how can you tell which item is in the wrong location if ¼-inch stove bolts are mixed with 5/16-inch nuts? (13-43, 44)

13. What should you do if you discover an empty oxygen bottle stored with full oxygen bottles? (13-45)

Section 14

Objectives: Given problems concerning inspection findings of work areas, equipment, and supplies, evaluate the findings and make recommendations for corrective action.

1. Suppose a shop inspection reveals that different types of scrap metals are mixed in the same containers. What should you do to correct the discrepancy before the metals are sent to redistribution and marketing? (13-13; 14-2)

2. The results of an inspection of the upper and lower cutter blades on the ring and circle shears shown in CRE figure 3 reveal that the blades are dull. What corrective action should you recommend if further inspection reveals that the blades are excessively worn? (14-6; CRE Fig. 3)

3. What corrective action should you recommend to the base supply bench stock section if an inspection of bench stock reveals that several items are stored in the wrong location, although the stock numbers and item descriptions are correct? (13-44, 14-11)

MODIFICATIONS

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ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

Section 1

1. STS 53132/52/72.

2. Crew leader.

3. The sheet metal supervisor (or foreman).

4*a*. The 5th, 6th, and 8th items.

4*b*. The 5th and 15th items.

Section 2

1*a*. Ten personality traits from the text:

Friendliness
Initiative
Ability to make decisions
Interest in people
Understanding
Sincerity
Pride in accomplishment
Patience and emotional control
Fairness
Personality

1*b*. Your list of five additional personality traits may include, or be similar to, those listed below. (Any five are acceptable provided that each describes qualities or patterns of behavior which will help a person to be a leader.)

Neat appearance
Cooperativeness
Courageousness
Creativity
Flexibility
Good humor
Power of observation
Ability to profit by experience
Resourcefulness
Sound judgment
Thoroughness
Truthfulness
Versatility

2. The supervisor was overlooking Airman Abbott's need of *recognition* for the good work he was doing with the trainees.

3. Physical capability of the worker.

4. Airman Cain probably lost interest in his job because he was shy and needed more encouragement than others might need; from the beginning he never knew where he stood. A supervisor should let each worker know how he is getting along.

5. *a.* Establish objectives.
   b. Gather facts.
   c. Take action.

6. Be a good listener and let the complaining worker do most of the talking.

Section 3

1. *c.*
   a.
   b.
   d.

2. *a.* Request type of instructions.
   b. Suggested or implied directions.
   c. Demand or direct type of directions.
   d. Request for volunteers.

3. By assigning the worker, on a rotational basis, to assist with the paperwork.

4. *a.* Time required should not be greater than ½ hour per joint.
   b. Completed components should reflect good workmanship in pattern development, cutting, forming, seaming, and assembly. Dimensions should be within 1/16-inch tolerance.
   c. Supervisory assistance should not exceed 20 percent of the task time.

5. *a.* Acceptable.
   b. Yes.
   c. Above average.

6. Subjective.

7. AF Form 77a, Letter of Evaluation.

8. Shop morale can be improved when workers get leave when desired.

CHAPTER 2

Section 4

1. In the plan view, lines AD and BC are too short and the diameter is too small.

2. No, because the half pattern in CRE figure 1 shows the addition to the base as 3 inches instead of 4 inches.

3. The 1-inch allowance for the Pittsburg pockets of the back piece must be increased to 1¼ inches if the pockets are to be formed on a cornice brake.

4. The notch near point G in CRE figure 1 is incorrect, because it should be only as deep as the seam allowance.

5. The instructions for the bottom addition should be up instead of down and should show the degree of bend. The seam allowances should have instructions for the bending.

Section 5

1. You should recommend utility shears because the gages and guides can be set for production work. Use of the utility shears will save time and effort and will probably make straighter cuts.

2. The back gage was set incorrectly at one end.

3. He has not adjusted the upper cutting blade tight enough to cut through the metal in one revolution.

4. Because he is not applying enough pressure on the unishears, the machine vibrates excessively.

5. The adjustable vise clamp was not tight enough to hold the metal securely.

6. You forgot to see if the trainee selected the correct size twist drill.

7. The Whitney punch.

8. *a.* See that the folds are being made in the correct locations, in the correct direction, and to the correct degree of bend.
   b. He should keep his hands away from the bed and bending leaf and should see that personnel are away from the counterbalance weight when it is moved.

9. He has the upper roll adjusted too tightly.

10. The supervisor should insure that the trainee does not overload the slip roll machine and that he does not bend rod except in the grooves provided for such work.

11. The trainee failed to turn the metal over when he made the second pocket.

12. Tell him that the ¼-inch flange should be on the opposite side of the sheet from the Pittsburg pocket. The flange should fit into the pocket when the sheet is formed into a rectangular shape.

13. *a.* A dovetail seam made on a 26-gage round duct joint should have tabs that are slit ½ inch and are ½ inch wide.
    b. A 1-inch standing seam to be made across a 24-gage rectangular duct joint should have an allowance of 1 inch for one side and 2 1/16 inches for the other side.

14. The roofing sheet will not have enough material to be folded into the cleat and bottom cap strip.

Section 6

1. You should start checking and supervising the layout operation because a mistake in the beginning will be wrong all the way through the operation.
2. The filter should be 12" x 20".
3. Since you found the drive slips to be the wrong size, have the trainee make some more from a pattern that is 2¼" x 14" so they will be long enough to bend over the ends of the S-slips.
4. The stack will lean toward the peak of the roof.

CHAPTER 3

Section 7

1. You should look for bent linkage or bent blades.
2. Inspect the seams of the roof jack and flashing, the holes where fasteners were pulled through the flashing, and the sealant used around the flashing.
3. Check for loose endlaps and sidelaps, loose fasteners, damaged fasteners, and any corrugated sheet that has pulled away from the fasteners.
4. Bronze nails 1 inch long should be used to refasten the bottom strip.
5. Look for loose hanger fasteners, broken hangers, broken seams, broken joint connections, and bent gutter.
6. Inspect for bends and breaks in the gutter, damaged hangers, loose fasteners, damaged end cap, damaged downspout drop outlet, damaged downspout, and damaged downspout hanger fasteners
7. Because most of the corrosion is in stage C and warrants replacing the tank rather than repairing it.
8. The remaining duct system components should also be checked for severe corrosion.
9. The early stages of corrosion that are present on hidden surfaces of flashing can be detected by the brown rust-colored streaks near the flashing.

Section 8

1. Permanent buildings.

2. Location of repair can be subdivided into (1) location on a component and (2) geographical location.
3. Yes.
4. No.
5. The decision should be to replace the damaged register with a new one.
6. Yes.

CHAPTER 5

Section 13

1. By checking block 11 of the work order for the chief of programs division's signature or initials.
2. You can check the work description and drawing against the materials list of supplies to see if the supplies are adequate for the job.
3. Acid fumes from an acid storage area located near the machines could cause the unpainted surface to rust.
4. You should send it to the fire extinguisher shop for a capacity check and replacement of the broken seal.
5. You should warn the workers that they must use the controlled smoking areas.
6. Scrap metal on the floors.
7. The gears should be painted orange.
8. Dirt and grease on the painted surface and dirty oil, rust, or grease on the unpainted surface.
9. Yes, the wheel guards are acceptable because they cover two-thirds of each grinding wheel.
10. Be sure the operator is wearing eye goggles or a face shield.
11. He failed to use an AF Form 333, Materials and Supplies Used, which should accompany the work order when bench stock materials are used.
12. Check the item description against the stock number and bin location number.

13. You should remove the empty bottle from the full bottle storage and place it with the empty bottles.

Section 14

1. The different types of metal should be separated and placed in the correct containers.
2. You should recommend that the dull and worn blades be replaced with new ones.
3. You should recommend that the location number for the items be checked and the numbers corrected.

MODIFICATIONS

Page 27 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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STOP– **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 OR NUMBER 2 PENCIL.**

53350 04 23

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: TEXT PAGE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Text Page Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Text Pages* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed*. Go to the VRE booklet and locate the *Text Page Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

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Multiple Choice

1. (002) Which of the following 5-level supervisory jobs will require the most proficiency in the fabrication of sheet metalwork?

   a. Checking performance of other workmen.
   b. Coordinating work with other shops.
   c. Planning an OJT program.
   d. Assigning tasks.

2. (003-005) Which of the following is a supervisory duty of the metalworking superintendent and is *not* a 5- or 7-level supervisory responsibility?

   a. Examines work orders for proper authorization.
   b. Assigns personnel to shops in the maintenance and repair branch.
   c. Regulates the use of space, equipment, and supplies.
   d. Insures timely completion of priority assignments.

3. (007-008) In the following situations, which individual difference will cause the worker to react differently?
   Example 1: Suppose the supervisor walked up to a technician in the sheet metal shop and said, "Say, Frank, I see that you finally got rid of that ventilator." The supervisor was referring to a ventilator that was a rather difficult transition to make Frank had worked very hard and was proud of the job. He took the supervisor's comment as somewhat of a commendation.
   Example 2: Now, suppose the same supervisor approached Frank in the same way and said the same thing. However, in this case, Frank had worked for many hours and was unable to make the ventilator work correctly. Another technician had quickly located the trouble as an error in the pattern development. Frank was somewhat angry at himself for not having found the error. He was standing at the workbench pondering over the situation when the supervisor came up with the same remark.

   a. Mental.
   b. Emotional.
   c. Physical.
   d. Social.

4. (009-010) Which of the following items is *not* included in organized problem-solving procedures?

   a. Build worker's confidence in your ability to handle people.
   b. Define the problem and establish the objective.
   c. Gather facts, weigh, and decide.
   d. Take action–evaluate action.

5. (010) Which of the following situations indicates a problem worker?

   a. A skin rash often causes him to be absent from work.
   b. He often disrupts work in the shop to initiate or participate in horseplay.
   c. Worry about the condition of his ailing mother interferes with his job.
   d. He has recently bought a car and is having difficulty making the payments.

6. (006-012) Which, if any, of the basic needs of people will be satisfied in an orientation such as the following? The supervisor continues to work at his desk when the new man arrives, mispronounces and fails to remember the new man's name, tells the new man what a good supervisor he is, and terminates the interview with the comment, "Go on out and meet the others."

   a. Security.
   b. Recognition.
   c. Opportunity.
   d. None of the above.

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7. (014) In the sheet metal shop, what type of work involves so many tasks that it minimizes the need for rotation of duty assignments?

   a. Driving the truck.
   b. Developing patterns.
   c. Taking service calls.
   d. Fabricating and installing.

8. (014) When making performance requirements (such as shown in figure 1 of the text), items in the requirements column must describe

   a. actual performance.
   b. acceptable performance.
   c. outstanding performance.
   d. unsatisfactory performance.

9. (017) In figure 2 of the text, which performance evaluation does *not* meet the acceptable requirement?

   a. Task a.
   b. Task b.
   c. Task c.
   d. Task d.

10. (017) Which of the following can be attached to an Airman's Performance Report (AF Form 909)?

    a. Annual rating form.
    b. Letter of evaluation.
    c. Supervisor's record of employee.
    d. Performance requirements rating chart.

Type of Seam	Gage of Metal and Decimal Equivalent	Lap Allowance (Width = W)	Size of Tinner's Rivets	Material Required		
				Formula	Side 1 or Piece 1	Side 2 or Piece 2
Flat Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Offset Lap	26 (0.018")	1/4"	1 lb	2 X W	1/4"	1/4"
	24 (0.025")	3/8"	2 lb	2 X W	3/8"	3/8"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	3/8"	3/8"
	20 (0.037")	3/8"	3 lb	2 X W	3/8"	3/8"
	16 (0.062")	1/2"	4 lb	2 X W	1/2"	1/2"
Corner Lap	26 (0.018")	1/4"	1 lb	2 X W	—	1/2"
	24 (0.025")	3/8"	2 lb	2 X W	—	3/4"
	22 (0.031")	3/8"	2 1/2 lb	2 X W	—	3/4"
	20 (0.037")	3/8"	3 lb	2 X W	—	3/4"
	16 (0.062")	1/2"	4 lb	2 X W	—	1"

530-3902

Volume Review Exercise Figure 1 for Question 11.

11. (021) You are checking the seam allowance on a pattern for an inside corner seam that is to be transferred to 16-gage metal. The trainee has made the seam allowance 1/2 inch wide. How much too narrow, according to Volume Review Exercise Figure 1, is the allowance?

    a. 1/4 inch.
    b. 5/16 inch.
    c. 1/2 inch.
    d. 9/16 inch.

12. (025) The patterns shown in figure 7 of the text have been transferred to metal and you are checking for mistakes. You find that the trainee has made two left side patterns. What caused the mistake?

    a. The same bend and hole instructions were marked on both patterns.
    b. Both patterns were marked for opposite bends.
    c. Both patterns were marked on the outside.
    d. Both patterns were marked on the inside.

13. (026) When instructing a trainee on the use of bench-mounted shears, which of the following safety precautions applies to the scroll shears, the throatless shears, and the utility shears?

    a. Allow sufficient clearance to properly operate the hand lever.
    b. Have another man hold large pieces of material.
    c. Keep fingers and hands clear of the rotary cutting blade.
    d. Do not turn on the electric power switch until all hands and fingers are clear of the cutting blade.

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14. (026) A trainee is using the ring and circle shears. You notice that the pattern has slipped, causing a defective cut although the yoke is adjusted correctly and has *not* slipped. What mistake did the trainee make in the cutting operation?

   a. The cutting head slipped.
   b. The feed gear slipped across the metal.
   c. The clamping discs were not tight enough.
   d. The cutting blades were too tight and grabbed the metal.

15. (026) You are supervising a trainee who is using portable unishears to cut a sheet of metal, and he has allowed the electric power cord to get between the two edges of the metal. What should you do?

   a. Tell the shop foreman about the incident.
   b. Stop the cutting operation and have a skilled workman make the cut.
   c. Stop the cutting operation and inform him not to use the unishears again.
   d. Stop the cutting operation, explain the mistake, and have him check the cord for cuts.

16. (027) The trainee you are supervising is ready to punch the water pipe holes in the side piece of the 16-gage shower stall shown in Figures 7 and 8 of the text. Your Whitney punch and hand lever punch can make holes 1½ inches from the metal edge. Your rotary punch can punch 20 inches from the metal edge. Your hollow punch can make a 1-inch-diameter hole in thin metal. Which of the punches should the trainee use?

   a. Hollow punch.
   b. Rotary punch.
   c. Whitney punch.
   d. Handlever punch.

17. (027) How many bends should there be for you to check if you are supervising a trainee who is using a cornice brake to fold the left side pattern shown in Figure 7 of the text?

   a. Two.
   b. Three.
   c. Four.
   d. Five.

18. (028) Which of the following should you check when a trainee is using the rotary burning machine to turn a 90° flange on a circular disc?

   a. The clamping discs.
   b. The upper roll.
   c. The gripping rolls.
   d. The feed pressure.

19. (028) When a trainee is learning to use a slip roll forming machine, the supervisor must check to see that the

   a. metal thickness does not exceed the rated capacity of the slip roll machine.
   b. rolls are lightly greased so that the metal will pass through easily.
   c. metal runs through the rolls lengthways rather than sideways.
   d. seam allowance is formed after a sheet is run through the slip roll machine.

20. (029) A trainee is forming sheet metal according to the back piece shown in figure 7 of the text. You are watching to see if he makes the Pittsburg seam correctly. What should he do?

   a. Make one Pittsburg pocket on the front side of the metal and the other on the back side.
   b. Make both flanges by running the seam allowances (same side of the sheet) through the Pittsburg lock forming machine.
   c. It doesn't make any difference whether he makes both flanges on the front side or the back side.
   d. Run both pocket allowances through the Pittsburg lock forming machine with the same side of the sheet up.

21. (037) What damage should you look for in a multiple blade register, such as the one shown in figure 17 of the text, if the control handle will operate the three lower horizontal blades but will *not* operate the two top horizontal blades?

a. Bent frame.
b. Bent blades.
c. Broken linkage.
d. Worn worm gear.

22. (037) After a high wind, inspection of a stack (such as the one shown in figure 16 of the text) reveals that the upper stack, storm collar, and vent cap need replacing. Which of the following should you check for leaks even though it was not bent during the storm?

a. Roof jack and flashing.
b. Ceiling thimble.
c. Lower stack.
d. Thimble.

23. (033; 039) When inspecting for wind damage, what type of metal roofing should be checked for loose cleats?

a. Batten seamed.
b. Corrugated.
c. V-crimped.
d. Ribbed.

24. (039) You are in charge of a crew which has repaired a fascia and gravel gurad flashing (such as that shown in figure 19 of the text) which had been torn loose from the bottom strip by high winds. The bottom strip has been removed and replaced. How far apart should the nails be in the bottom strip?

a. 2 inches.
b. 4 inches.
c. 6 inches.
d. 8 inches.

25. (039) Which of the following will likely need replacing if inspection of the damage to an aluminum gutter (such as the one shown in figure 20 of the text) reveals that the gutter has been hit by a falling limb at a point where two sections are jointed?

a. Slip joint.
b. Miter joint.
c. End cap.
d. Downspout drop outlet.

26. (043) What is the main characteristic that can be used to identify moderate corrosion under a metal surface that is painted?

a. Pits.
b. Holes.
c. Blisters.
d. Brown spots.

27. (043) When inspecting a galvanized roof jack and flashing (like the one shown in figure 16 of the text) for signs of corrosion, on which side of the flashing should you look for brown streaks? Between the flashing and the

a. peak of the roof.
b. eave of the roof.
c. gable of the roof.
d. valley of the roof.

28. (044) What metal would you likely use for replacing a damaged section of gutter on a semipermanent type building which is located in a region that has a dry climate?

a. Tin.
b. Copper.
c. Black iron.
d. Galvanized iron.

29. (044) A ceiling diffuser is to be replaced. In which of the following listed locations will the largest amount of man-hours be required for the replacement?

a. The entrance hallway of a service club.
b. The office of a warehouse.
c. An orderly room.
d. An aircraft hangar.

30. (045) How much stainless steel is needed to make the pattern (including allowances and additions) for the right side of the hood shown in figure 6 of the text?

a. 30" x 55 7/16".
b. 34 1/8" x 44 1/2".
c. 34 1/8" x 55 7/16".
d. 36 7/16" x 96".

31. (046) You have cleaned 3 small spots of corrosion on an upper stack joint (such as shown in figure 16 of the text) and you determine that the joint should be replaced instead of patched. The flashing, which is lightly corroded, should be

a. replaced along with the stack joint.
b. patched and sealed.
c. scraped and painted.
d. left alone until the corrosion becomes more severe.

32. (052) Which of the following would classify a shop-referred service call as emergency?

a. Heat loss in a building when the outside temperature is -10°.
b. Repair of a furnace stack when the outside temperature is 95°.
c. A metal window latch that is broken in the closed position and the outside temperature is -10°.
d. Repair of a closed metal exhaust louver when then outside temperature is 25°.

33. (052) A job has to be stopped because of exhausted supplies. A materials list has been made and turned in to the materiel control section, and the crew is assigned to another job. What should be done next by the shop supervisor?

a. Research stock numbers for the materials list.
b. Pick up materials for the job.
c. Check other jobs to see if materials are available.
d. Notify the scheduler of the change.

34. (054) The AF Form 561 is usually prepared on

a. Monday.
b. Tuesday.
c. Friday.
d. the last day of the month.

35. (054) The nonproductive time is figured on the number of

a. working days in a week.
b. hours spent on lag time each week.
c. assigned persons.
d. authorized slots.

36. (054) To find the available man-hours, multiply the number of

a. available man-hours by 8.
b. available men by 8.
c. working days by available manpower.
d. available manpower by the working days.

37. (054) Once the schedule is prepared by the scheduler and sent to the shop, it

a. becomes the controller's responsibility to make the daily entries on AF Form 561.
b. is sent to the flight line for a time check.
c. is duplicated and sent to quality control.
d. is signed by the base inspector, after checking all entries for accuracy.

38. (054) The scheduler makes out AF Form 561 in

a. triplicate.
b. duplicate.
c. 6 copies.
d. 1 original and 2 carbon copies.

39. (056) Which of the following should the shop supervisor do if it is necessary to have a crew leader for a job?

a. Assign the workers to another crew who already have a leader.
b. Lead the crew himself.
c. Have the crew stand by and charge the time to awaiting assignment.
d. Assign the ranking member as the crew leader.

40. (064) How many pairs of 4-pound nonelectric soldering irons are authorized for a shop that has 10 sheet metalworkers?

a. 2.
b. 4.
c. 6.
d. 8.

41. (065) How many items were back ordered on TA 503 as shown in figure 32 of the text?

a. None.
b. 1.
c. 2.
d. 6.

42. (067) A sheet metal shop has completed a job authorized by a work order and has one whole roll of insulation left over. What form is used to turn in the leftover material?

a. AF Form 333.
b. AF Form 601b.
c. DD Form 1150.
d. AF Form 1445.

43. (067) Figure 35 of the text shows sample entries for AF Form 333. Where will the sheet metal technicians who are assigned to perform work order 250-7 get the 26 square feet of 18-gage galvanized sheet metal?

a. Scrap.
b. BEMO.
c. Bench stock.
d. BCE holding area.

44. (068) What form should be used to request a one-time issue of a box of 3003 aluminum countersunk rivets?

a. AF Form 333.
b. AF Form 60lb.
c. DD Form 1150.
d. AF Form 1445.

45. (069) A work order is received in the sheet metal shop. What should the shop supervisor do if block 11 of the work order (AF Form 327) is blank?

    a. Submit a change order.
    b. Place his initials in block 11.
    c. Return it for proper authorization.
    d. Go ahead with the job specified on the work order.

46. (071) Which of the following actions should you take if the shop inspection reveals a broken seal on one of the fire extinguishers?

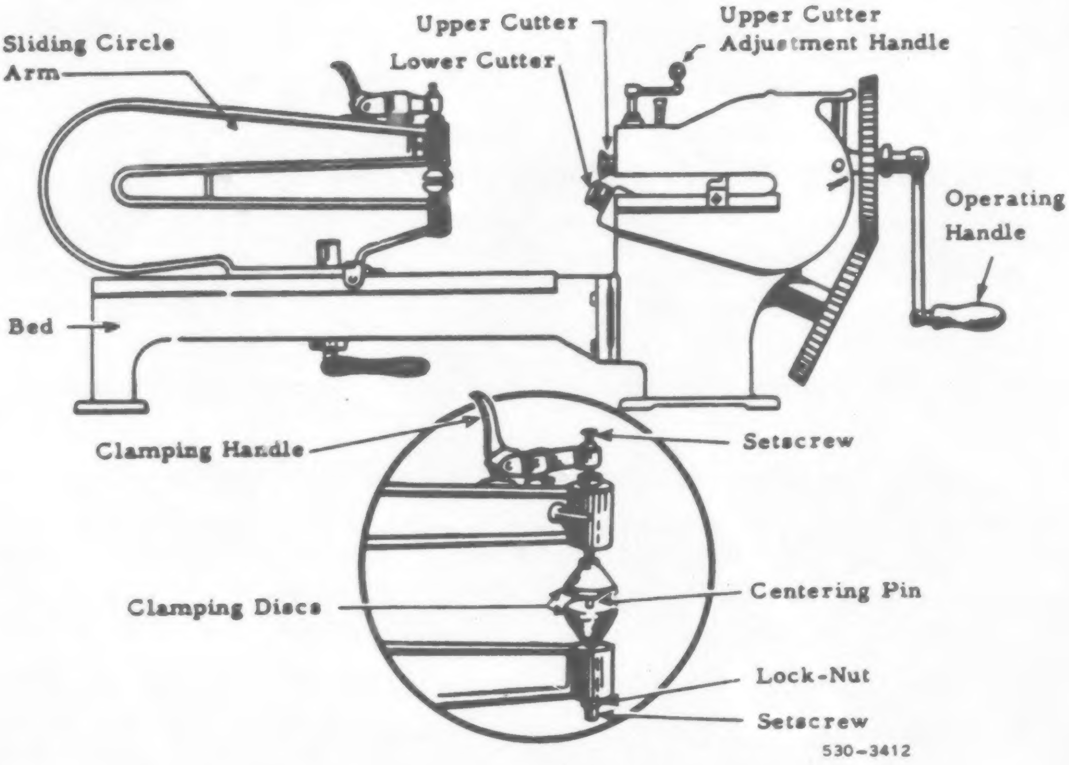
    a. Replace the seal.
    b. Have the extinguisher inspected or recharged.
    c. Place a condemned tag on the extinguisher.
    d. Test the extinguisher by depressing the discharge handle.

47. (072) As a crew leader at a job site where flammable gases are present, you should check to see that

    a. windows are closed.
    b. face masks are used.
    c. no-smoking restrictions are observed.
    d. security restrictions are complied with.

48. (072) Which of the following are included in the cleanliness inspection for the rolls of the slip roll forming machine shown in figure 38 of the text?

    a. Red painted rolls.
    b. Ivory painted rolls.
    c. Orange painted rolls.
    d. Corrosion-free rolls.


Sliding Circle Arm
Upper Cutter
Lower Cutter
Upper Cutter Adjustment Handle
Operating Handle
Bed
Clamping Handle
Setscrew
Clamping Discs
Centering Pin
Lock-Nut
Setscrew
530-3412

Volume Review Exercise Figure 2 for Question 49.

49. (072) Ring and circle shears (like the one shown in Volume Review Exercise Figure 2) are delivered to the shop without color markings. What color of paint should be applied to the gears which are driven by the operating handle?

a. Red.	c. Ivory.
b. Gray.	d. Orange.

50. (074) What, if anything, should you recommend if your inspection of a bench grinder reveals that the work rests are 3/32 inch from the grinding wheels?

a. No recommendation is needed.
b. The work rest should be moved back 1/8 inch.
c. The work rest should be moved forward 1/16 inch.
d. Do not allow anyone to use the grinder until it is adjusted properly.

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51. (076) What should you look for when checking a work order (AD Form 327) that has required materials which are charged to another work order?

a. The work order number of AF Form 327 should be changed.
b. AF Form 333, Materials and Supplies Used, should be attached.
c. AF Form 1445, Materials and Equipment List, should be attached.
d. The borrowed materials should be listed on the work order which you are checking.

52. (076) During a bench stock inspection, you find that 1½-pound tinner's rivets are stored in the bin designated for 3-pound tinner's rivets. Which of the following is the probable cause?

a. Location number incorrect.
b. Class code number incorrect.
c. Incorrect weighing of the rivets.
d. Bench stock work order number incorrect.

53. (071-077) What corrective action should you take if scrap metal is *not* kept off of the shop floor?

a. Notify the safety inspector.
b. Containers should be clearly marked.
c. The containers should be painted orange.
d. Scrap metal should be picked up and all personnel instructed to use proper containers.

54. (077) What corrective action should be taken before further use if the centering pin of the ring and circle shears, Volume Review Exercise Figure 2, is broken?

a. Replace the centering pin.
b. Soft solder the centering pin.
c. Resistance weld the centering pin.
d. Sweat solder the centering pin with 50/50 solder.

55. (076; 078) What corrective action should you recommend if an inspection of bench stock reveals that items added at the last inventory do not have location numbers?

a. Remove the items from the storage areas.
b. Assign the added items a document number.
c. Turn in the added items to BCE materiel control.
d. Remove the added items from the bench stock listing.

56. (080) What document contains all of the tasks that an airman is required to perform?

a. CDC.
b. JPG.
c. OJT.
d. STS.

57. (084) An airman in the sheet metal shop is being transferred. What action should be taken concerning the JPG record of items in which he has become proficient? (He may *not* be required to perform these same items at his next duty station.)

a. Mark through the JPG with a red pencil.
b. Record the JPG items on a separate AF Form 623.
c. Leave the JPG in his on-the-job training record.
d. Remove the JPG from his on-the-job training record.

58. (084) What Air Force manual should you consult concerning how to make entries on AF Form 623?

a. AFM 50-20.
b. AFM 50-23.
c. AFM 50-24.
d. AFM 50-25.

59. (085) What skill level should an airman possess in order to be assigned as a trainer for one or more tasks?

a. 3 level.
b. 5 level.
c. 7 level.
d. Any of the above.

60. (086-087) What can you do to keep a trainee interested in a job training exercise? Train him

a. in the hardest tasks first.
b. to do only the easiest tasks.
c. in all phases of the exercises.
d. in phases that he does not already know.

61. (088) What mistake has a trainer made in the use of training technique if, while giving instructions for fabricating grooved seams, he starts explaining how to make a riveted lap seam?

a. He is presenting too many instructions at one time.
b. The first situation was not repeated before going to another.
c. He should have explained riveted seams first because they are easier to make.
d. He failed to have the trainee make a grooved seam before going on to the riveted lap seam.

62. (089) What training device prepared by the trainer contains a list of key points that should be emphasized when teaching a trainee to perform a task?

a. Job proficiency guide.
b. Task breakdown.
c. Job training standard.
d. Specialty training standard.

63. (089) A trainee has progressed to the point where he is to form a rectangular duct joint without supervision. What followup procedure should you (the trainer) use? Check the

a. machine adjusting operation.
b. assembly operation.
c. completed joint.
d. bending operation.

64. (090) Why is it important for the trainee to do his best when taking the career development course for his AFSC?

a. A high grade will insure that he gets promoted.
b. The knowledge gained will help him progress in his career area.
c. Completion of the CDC will make him proficient in the STS and JPG items.
d. The knowledge gained will determine his skill on the job.

65. (090) What is the most important reason for a trainee to complete the chapter review exercises in his CDC workbook?

a. To help him achieve the knowledge code level specified in the STS.
b. So that the trainer can evaluate the trainee's proficiency.
c. It helps him learn to solve problems.
d. So that he can learn by doing.

66. (090) What is needed by a trainee who is *not* progressing satisfactorily in the career knowledge development portion of his OJT?

a. Supervised study.
b. More time to study on his own.
c. Review of the CREs; then retake the VRE.
d. Additional job instruction from the trainer.

67. (091) What prevents the course examination from being compromised?

a. It is an open-book test.
b. The squadron training NCO.
c. The use of study reference guide numbers.
d. The review efforts of failing students are supervised.

68. (091-093) When making work assignments in the sheet metal shop, how can the best proficiency in training be accomplished?

a. Give each worker training in all tasks performed by your shop.
b. Have group instruction for parts of the CDC.
c. Assign trainees to work together so that they can help each other.
d. Have the trained men to conduct discussions on how jobs are done.

69. (093) What is a good tool for a supervisor to use to evaluate the effectiveness of a man who is teaching a new man to perform a task?

a. Job proficiency guide.
b. Performance requirement.
c. Demonstration check sheet.
d. Specialty training standard.

70. (093) Each of the following are responsibilities of the shop supervisor *except* to

a. perform necessary training where possible and practicable.
b. see that trainees are upgraded as soon as practicable.
c. select trainers with the best leadership qualities.
d. visit the shop frequently and know the training status.